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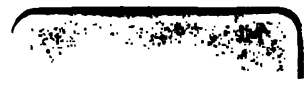

GEORGE LEWIS.

PRESIDENT OF THE INSTITUTION OF MINING ENGINEERS, 1892-1893.

TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

VOL. XIX.—1899-1900.

EDITED BY M. WALTON BROWN, SECRETARY.

NEWCASTLE-UPON-TYNE: PUBLISHED BY THE INSTITUTION.

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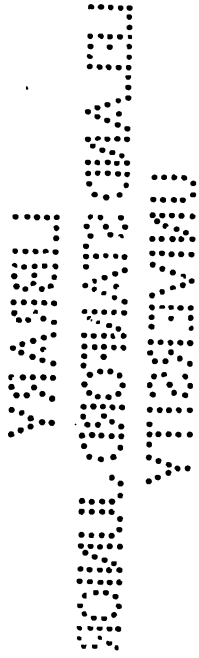

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ANY PUBLICATION OF A FEDERATED INSTITUTE MAY BE PLACED AT THE END OF THE VOLUME, *i.e.*, "ANNUAL REPORT," "LIST OF MEMBERS," ETC.

THE INSTITUTION OF MINING ENGINEERS.

FOUNDED JULY 1ST, 1889.

BYE-LAWS

As revised at Council Meeting held on July 13th, 1898.

I.—CONSTITUTION.

1.—The Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering and their allied industries, who shall from time to time join together and adhere to the Bye-Laws.

2.—The Institution shall have for its objects—

(*a*) The advancement and encouragement of the sciences of mining, metallurgy, engineering, and their allied industries.

(*b*) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.

(*c*) The publication of original communications, discussions, and other papers connected with the objects of the Institution.

(*d*) The purchase and disposal of real and personal property for such objects.

(*e*) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

II.—MEMBERSHIP.

6.—The original adherents or founders are as follows:—

(*a*) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.

(*b*) Midland Institute of Mining, Civil and Mechanical Engineers, Barnsley.

(*c*) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

(*d*) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their Bye-Laws, in order that their members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model Bye-Law to be adopted by any society when so desired by the Council.

B.—"The members shall consist of Ordinary Members, Associate Members and Honorary Members, with Associates and Students:—

(*a*) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.

(*b*) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.

(*c*) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.

(*d*) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.

(*e*) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

III.—Subscriptions.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

IV.—Election of Officers and Council.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute, in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one Vice-President per two hundred Ordinary Members or Associate Members thereof; and of a President elected by and from the Council at their first meeting in each year; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

V.—Duties of Officers and Council.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and Bye-Laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda-paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining, metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer and the Secretary after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountants' charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

VI.—General Meetings.

38.—An ordinary general meeting shall be held in February, May and September, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st. shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

VII.—Publications.

41.—The publications may comprise:—

(*a*) Papers upon the working of mines, metallurgy, engineering, railways and the various allied industries.

(*b*) Papers on the management of industrial operations.

(*c*) Abstracts of foreign papers upon similar subjects.

(*d*) An abstract of the patents relating to mining and metallurgy, etc.

(*e*) Notes of questions of law concerning mines, manufactures, railways, etc.

42.—Each paper (with complete drawings, if any, to scale), to be read at any meeting of the Institution or of any of the Federated Institutes, shall be placed in the hands of the Secretary at least fourteen days before the date of the meeting at which the paper is to be read, and shall, subject to the approval of the Council, be printed, together with any discussion or remarks thereon.

43.—The Council may accept communications from persons who are not members of the Institution and allow them to be read at the ordinary or annual general meetings.

44.—No paper which has already been published (except as provided for in Bye-Law 41) shall appear in the publications of the Institution.

45.—A paper in course of publication cannot be withdrawn by the writer.

46.—Proofs of all papers and reports of discussions forwarded to any person for revision must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

47.—The copyright of all papers accepted for printing by the Council shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

48.—Twenty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the cover shall state that it is an "Excerpt from the Transactions of The Institution of Mining Engineers."

49.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchanges shall be paid for at cost price.

50.—The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

51.—A list of the members, with their last known addresses, shall be printed in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by the Council:—to non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 15s.

54.—The Institution as a body is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution, or of the Federated Institutes.

VIII.—Medals and other Rewards.

55.—The Council may award annually the sum of twenty pounds, in the form of medals or other rewards, to the authors of papers published by the Institution.

IX.—Property.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council

57.—The Institution may make use of the following receipts for its expenses:—

(*a*) The interest of its accumulated capital fund;

(*b*) The annual subscriptions; and

(*c*) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

X.—Alteration of Bye-Laws.

61.—No alteration shall be made in the Bye-Laws of the Institution, except at a special meeting of the Council called for that purpose, and the particulars of every such alteration shall be announced at their previous meeting and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the Bye-Laws, subject to confirmation by the next ensuing Council meeting.

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BRIDGEWATER TRUSTEES, Bridgewater Offices, Walkden, Bolton-le-Moors, Lancashire.
BUTE, MARQUESS OF, Bute Estate Office, Aberdare, South Wales.
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VICTORIA GARESFIELD COLLIERY, OWNERS OF, Victoria Garesfield Colliery, Lintz Green, Co. Durham.

WEARMOUTH COLLIERY, OWNERS OF, Sunderland.
WESTPORT COAL COMPANY, LIMITED, Manager, Dunedin, New Zealand.

Non-Federated.

* Deceased.

ADAM, WILLIAM, Blantyre Saw Mills, High Blantyre, Glasgow.
AITKEN, HENRY, Darroch, Falkirk, N.B.

BAXTER, ANDREW, Whifflet Station, Coatbridge, N.B.
BRYSON, D. R., 45, Hope Street, Glasgow.
BUCHANAN, Sir DAVID CARRICK, Drumpellier, Coatbridge, N.B.

CAMERON, WILLIAM, Finnie Street, Kilmarnock, N.B.
CARMICHAEL, ROBERT, Bellfield Colliery, Coalburn, Lesmahagow, N.B.
CRANSTON, DAVID, Woodend Colliery, Armadale, Linlithgowshire.

*DANKS, HENRY, Green Colliery, Wishaw, N.B.

FERGUSON, DAVID, 140, Hyndland Drive, Kelvinside, Glasgow.
FERGUSON, DUNCAN, Lochore and Capeldrae Collieries Lochgelly, R.S.O., Fifeshire.

GIBB, WALTER, Tannochside Colliery, Uddingston, N.B.

HOOD, ARCHIBALD, 6, Bute Crescent, Cardiff.
HYSLOP, WILLIAM, Bank Colliery, New Cumnock, R.S.O., Ayrshire.

KELSO, JOHN, Ferniegair Colliery, Hamilton, N.B.
KESSON, ANDREW, Clydebank House, Bothwell, Glasgow.
KING, PETER, Darngavil, Airdrie, N.B.

LOGAN, WILLIAM, 6, Merchiston Place, Edinburgh.

M'CULLOCH, JOHN, Shieldhill Colliery, Falkirk, N.B.
M'DONALD, JOHN, Greenhill Colliery, Holytown, R.S.O., Lanarkshire.
M'GILL, JAMES, Bog House, Hollandbush, Bonnybridge, R.S.O., Stirlingshire.
M'KILLOP, JAMES, Polmont Park, Polmont, Stirlingshire.
MORROW, SAMUEL, Palacecraig, Airdrie, N.B.

NASMYTH, J. A., Donibristle Colliery, Crossgates, Fife.

ROBERTSON, DAVID, 135, Waterloo Street, Glasgow.
ROBERTSON, JOHN, Jun., 12, St. Vincent Place, Glasgow.
RUSSELL, ARCHIBALD, Jun., Mouswald Place, Ruthwell, R.S.O., N.B.
RUSSELL, JOSEPH, Newton Colliery, Newton, Glasgow.
RUSSELL, P. B., 10, Regent Terrace, Edinburgh.
RUSSELL, ROBERT, Coltness Iron Works, Newmains, R.S.O., Lanarkshire.

SMITH, EUSTACE, Jun., St. Lawrence Ropery, Newcastle-upon-Tyne.

WEIR, THOMAS D., c/o Brown, Mair, Gemmell and Hislop, 162, St. Vincent Street, Glasgow.
WHITE, WILLIAM, 46, Bothwell Square, Bothwell, N.B.
WYLIE, JOHN, Clifton Iron Works, Coatbridge, N.B.

YOUNG, WILLIAM 109, St. Vincent Street, Glasgow.

THE INSTITUTION OF MINING ENGINEERS.

BENEVOLENT FUND.

The Council are of opinion that the experience of the past has proved the desirability of forming a Benevolent Fund in connexion with The Institution of Mining Engineers, similar to the Benevolent Fund of the Institution of Civil Engineers, established in 1864, when the membership of that Institution was much less (1,040) than the present membership (2,500) of this Institution. There is no doubt that a well-managed and adequately-supported Benevolent Fund would prove advantageous to members who may be overtaken by misfortune. It is suggested that the Benevolent Fund should be incorporated as an association under the Companies Acts, but with the word "limited" omitted by license of the Board of Trade. The Articles of Association should include the following :—

1.—This Institution shall be called "The Benevolent Fund of the Institution of Mining Engineers."

2.—The object of the Benevolent Fund is to afford assistance to necessitous Members, Associate Members, Associates and Students of The Institution of Mining Engineers and their families.

3.—The Fund shall be supported by means of Donations and Bequests, and by Annual Subscriptions.

4.—Contributors to the Fund shall be entitled to vote at all General and Extraordinary General Meetings.

5.—The affairs of the Fund shall be conducted by the "Committee of Management," consisting of seven members, and composed as follows:—The President, for the time being, of The Institution of Mining Engineers, and six Contributors to the Fund.

6.—The Committee of Management shall have full power to make grants and afford assistance to any necessitous Member, Associate Member, Associate or Student of The Institution of Mining Engineers, or to their families.

7.—The names of the applicants for, and the recipients of, the assistance afforded by the Fund, shall not necessarily be published.

8.—The fact of having been a Contributor to the Fund shall not in any case constitute a claim to participate in it.

9.—The Committee of Management shall not make any grants or payments by which the donations, bequests, or income of future years shall be anticipated, or appropriated.

September 18th, 1900.

THE INSTITUTION OF MINING ENGINEERS.

SUBJECTS FOR PAPERS.

The Council of The Institution of Mining Engineers invite original communications on the subjects in the following list, together with other questions of interest to mining and metallurgical engineers.

For selected papers, the Council may award prizes. In making awards, no distinction is made between communications received from members of the Institution or others.

Assaying.
Automatic coupling of mineral wagons.
Blowing out of coal and minerals *in situ*.
Boiler explosions.
Bore-holes and prospecting.
Boring against water and gases.
Brickmaking by machinery.
Brine-pumping.
Canals, inland navigation, and the canalization of rivers.
Coal-getting by machinery.
Coal-washing machinery.
Coke manufacture and recovery of bye-products.
Colliery leases, and limited liability companies.
Compound winding-engines.
Compressed-air as a motive-power.
Consumption of steam and water in engines.
Corrosive action of mine-water on pumps, etc.
Descriptions of coal-fields.
Diamond-mining.
Distillation of oil-shales.
Drift and placer-mining.
Duration of coal-fields of the world.
Electric mining lamps.
Electricity and its applications in mines.
Electro-metallurgy of copper, etc.
Engine-counters and speed-recorders.
Explosions in mines.
Explosives used in mines.
Faults and veins.
Fuels and fluxes.
Gas-producers, and gaseous fuel and illuminants.
Gas, oil and petroleum engines.
Geology and mineralogy.
Gold-recovery plant and processes.
Haulage in mines.
Industrial assurance.
Inspection of mines.
Laws of mining and other concessions.
Lead-smelting.
Light railways.
Lubricating value of grease and oils.
Lubrication of trams and tubs.
Maintenance of canals in mining districts.
Manufacture of fuel-briquettes.
Mechanical preparation of ores and minerals.
Mechanical ventilation of mines, and efficiency of the various classes of ventilators.
Metallurgy of gold, silver, iron, copper, lead, etc.
Mineral resources of colonies.
Mining and uses of arsenic, asbestos, bauxite, mercury, etc.
Natural gas, conveyance and uses.
Occurrence of mineral ores, etc.
Ore-sampling machines.
Petroleum-deposits.
Preservation of timber.
Prevention of over-winding.
Pumping machinery.
Pyrometers and their application.
Quarries and methods of quarrying.
Rectification of mineral oils.
Rock-drills.
Safety-lamps.
Salt-mining, etc.
Screening, sorting and cleaning of coal.
Shipping and discharge of coal-cargoes.
Sinking, coffering and tubbing of shafts.
Sleepers of cast-iron, steel and wood.
Smelting.
Spontaneous ignition of coal and coal-seams.
Stamp-milling.
Steam-condensation arrangements.
Steam-power plants.
Submarine coal-mining.
Subsidences caused by mining-operations.
Sulphur-mining.
Surface-arrangements of mines.
Surveying.
Tin-mining.
Transport on roads.
Tunnelling, methods and appliances.
Utilization of dust and refuse coal.
Utilization of sulphureous gases resulting from metallurgical processes.
Ventilation of coal-cargoes.
Ventilation of mines.
Water as a motive-power in mines.
Water-tube boilers.
Watering coal-dust.
Water-incrustations in boilers, pumps, etc.
Winding arrangements at mines.
Winning and working of mines at great depths.

TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

HELD IN THE MUNICIPAL TECHNICAL COLLEGE, DERBY, DECEMBER 2ND, 1899.

MR. M. H. MILLS, VICE-PRESIDENT, IN THE CHAIR.

DEATH OF MR. HENRY LEWIS.

The CHAIRMAN, referring to the recent death of Mr. Henry Lewis, of Annesley, one of their Past-Presidents, said that he was well known to the members, and they must feel that not only had they lost a genial friend but that the coal-mining industry had lost one of its best managers.

Mr. J. H. W. LAVERICK (Pye Hill) said that he had known Mr. H. Lewis for a quarter of a century, in fact from his earliest years. Every association connected with Mr. Lewis was of the most kindly description—a better-hearted man never breathed in the coal-trade—and he moved that a vote of condolence be sent to Mr. George Lewis, his brother, and the other relatives he had left behind.

Mr. C. LATHAM (University College, Nottingham), in seconding the proposal, said that he would like, as representing the mining students of the city and county of Nottingham, to cordially

endorse the remarks which had already been made. Mr. H. Lewis took the deepest interest in the well-being of the young mining students of the county, and they all very deeply regretted his death.

The resolution was unanimously adopted.

The SECRETARY announced the election of the following gentlemen: —

MEMBERS—

Mr. W. PRICE ABELL, Engineer, Castle Hill, Duffield, Derby.
Mr. S. A. EVERETT, Mining Engineer, Gedling, Nottingham.
Mr. THOMAS GREENSMITH, Mining Engineer, Eckington Collieries, Sheffield.
Mr. P. J. E. KENNEDY, Electrical Engineer, Digby Colliery, Nottingham.
Mr. ARTHUR B. MARKHAM, Colliery Owner, Stuffynwood Hall, Mansfield.
Mr. JOHN NEVINS, Langwith Colliery, Mansfield.
Mr. ALBERT J. A. ORCHARD, Mining Engineer, The White House, Nailstone Wood, Leicester.
Mr. J. G. SHEARER, Mechanical Engineer, Langwith Colliery, Mansfield.
Mr. F. W. WHEATLEY, Mining Engineer, 47, Trent Boulevard, Nottingham.

ASSOCIATES—

Mr. ELIJAH JACKSON, Enginewright, Langwith Colliery, Mansfield.
Mr. JOHN THOMPSON, Deputy, Langwith Colliery, Mansfield.
Mr. GEORGE WALKER, Under-manager, Langwith Colliery, Mansfield.

DISCUSSION OF MR. HENRY DAVIS' PAPER ON "COAL-CUTTING MACHINERY"*; MR. G. CLARENCE ALLSEBROOK'S PAPER ON "COAL-CUTTING BY MACHINERY"†; MR. THOMAS H. BARR'S PAPER ON "TWO TYPES OF ELECTRICAL COAL-CUTTERS"‡; MR. W. T. GOOLDEN'S PAPER ON "COAL-CUTTING BY MACHINERY"‖; MR. W. D. L. HARDIE'S PAPER ON "MACHINE-MINING AND PICK-MINING COMPARED"§; AND MR. BENAIAH PARKER'S "NOTES ON COAL-CUTTING MACHINERY IN USE AT FOXFIELD COLLIERY."‡‡

The CHAIRMAN (Mr. M. H. Mills) said that although few of the members had probably seen pick-machines in actual use, still they must recognize that, under many circumstances, they would be of great value especially in opening out. Where there was very

* *Trans. Inst. M.E.*, vol. xix., page 5.
† *Ibid.*, vol. xvi., page 67; and vol. xvii., page 257.
‡ *Ibid.*, vol. xvi., page 447; and vol. xviii., page 80.
‖ *Ibid.*, vol. xv., page 378; vol. xvi., page 266; and vol. xvii., pages 221 and 273.
§ *Ibid.*, vol. xvii., page 171; and vol. xviii., page 81.
‡‡ *Ibid.*, vol. xvii., pages 238 and 595.

hard holing there was no doubt that a pick-machine would prove of considerable utility in thin seams.

Mr. J. H. W. Laverick believed that one of the objections to the percussion-machine was that the reciprocating action punished the workman who handled the machine more than a hard day's work would. He asked whether this difficulty had been overcome, and whether the machine could hole at the top of a seam.

Mr. G. J. Binns (Derby) said that his experience of pick-machines dated back about 12 years, when he saw and tried one in a New Zealand mine. The work for a beginner was exceedingly hard, but when a workman became proficient there was nothing like the same amount of strain. A considerable number of reciprocating machines (which were simply rock-drills with wheels) were now used in New Zealand, and they were found to be very useful. One of the greatest difficulties in a percussion-machine was to obtain a valve which did not leak, stick, or wear out.

Mr. H. R. Hewitt (H.M. Inspector of Mines) asked whether any appliance for removing the holing-dirt was used with the Sullivan machine, so as to prevent any interference with each successive stroke of the pick. Without such an arrangement the pick would strike against the loose holing-dirt, and would therefore be using power to no purpose. Possibly the machine was stopped frequently, in order that the holing-dirt might be removed by hand. A great feature in modern coal-cutting machines was that the cutters automatically carried the holing-dirt to the front of the coal-seam, where it could be readily thrown back into the goaf.

Both Mr. Parker and Mr. Barr described the Hurd bar-machine, but he thought it was generally understood that the disc-machine was the best, for reasons which had frequently been stated. The principal objection to a cutter-bar was that it was too human in its work: it would find the easiest place in which to work, and as the coal is usually softer than the holing-dirt, the cutter-bar was continually climbing into it. The cutter-bar, however, would cut its way into and out of its work, whereas manual labour was required for the same purpose with the disc-machine. Mr. Hurd stated that the Hurd machine driven electrically was not safe in a gaseous mine, whereas Mr. Barr said that there was nothing exposed except the trailing cables. If this

latter statement be correct, it would appear to be a simple matter to cover up the machine in such a manner that the former objection is rectified. The Clark machine was stated by Mr. Barr to have holed 450 feet per shift, and the Hurd machine 264 feet in 8 hours. Mr. Goolden was satisfied if a machine holed 300 feet per shift, and he thought that mining engineers would agree with him. The usual average holing in the Midland district was not more than 180 feet per shift, and this was considered very satisfactory. One machine had been tried for 6 months in a Derbyshire coal-mine and did very little work during that time; but in the last day of its working it managed to cut 51 feet in 15 hours, when everything was supposed to be in working order, and the machine was under proper supervision.

Mr. H. Davis said that he was assured by American mining engineers that the health of the workmen was not injured by the use of the reciprocating machine, and that they could always get more men than they wanted. Mr. W. D. L. Hardie stated that "we hear a good deal about machines shaking runners to pieces, but there is no foundation for such statements."* Mr. Binns confirmed his information as to the non-injury of the operator. The Sullivan machine was not fitted with any appliance for removing the holing-dirt, and two men were required to work the machine. One sat and operated the machine, while the helper shovelled away the slack coal as it was made. The slack consisted of pieces of coal of about 1 inch cube. There would be no difficulty in mounting a pick-machine on large wheels, to enable it to strike horizontally in that portion of the seam which they wished to remove; and it would hole equally well at the top or in any portion of the seam.

ALTERATIONS OF RULES.

The Chairman moved that the alterations in the Rules of the Institution, notice of which was given at the Annual General Meeting, held on August 26th, 1899, be adopted.

Mr. C. R. Hewitt (Derby) seconded the proposition, which was unanimously agreed to.

Mr. Henry Davis read the following paper on "Coal-cutting Machinery":—

* *Trans. Inst. M.E.*, vol. xvii., page 177.

COAL-CUTTING MACHINERY.

By HENRY DAVIS.

The writer having recently visited the United States of America has had opportunities of viewing various coal-cutters at work and of gleaning information which he hopes may prove of some interest. The present paper deals exclusively with that type of coal-cutting machine which has a reciprocating or punching action, and although very little used in the United Kingdom might with advantage be largely employed. This class of coal-mining machine consists of an air-cylinder with valves and either air-cushion or leather-cushion, a piston and shaft which carries the chisel or pick; the cylinder is fitted with two handles at the rear and is mounted on a pair of wheels. The machine is placed on a board about 6 or 7 feet long by 36 inches wide, with a trestle at the far end forming a plane inclining to the coal-face which may be varied with the dip or rise of the seam.* The operator sits upon this inclined plane, takes hold of the two handles, and his feet rest against suitable brackets which form part of the machine. To avoid undue wear-and-tear, he is provided with a leather-apron upon which he sits.

The punching-machine is worked by air-power; so far electricity has not been successfully applied, although many attempts have been made. The most efficient air-pressure varies from 70 to 80 pounds per square inch, though 40 pounds will suffice. The average free air consumed is 75 cubic feet per minute at the air-compressor; this is brought from the mains to the coal-face in pipes, 1¼ inches in diameter, and usually 50 feet of flexible four-ply hose, 1 inch in diameter, is used with each machine.

The operator sitting upon the inclined board (previously described) directs the blow, his limbs are held freely, with knees raised and elbows outwards, and by this means his body does not receive any shock, the recoil being taken by the machine. The writer was assured that no ill effects are felt by the operator, and

* *Trans. Inst. M.E.*, vol. xiii., page 482, Fig. 1.

notwithstanding that about 2,500 machines are in use, there are always more men applying for work than there are machines for the applicants. The punching-machine is worked by one man, and a helper is employed to clear away the slack coal. The construction is simple and any intelligent miner is able to work a machine within a week. The compactness and the lightness of the punching-machine will commend itself, and although it is mostly employed for pillar-and-stall workings it may equally well be used in longwall workings, where the conditions are favourable to the employment of machines especially built for the system.

The outward stroke of the pick is about 300 per minute, and the inward 60—this means 180 blows per minute. The depth of efficient holing is 5 feet: although special machines are made to hole 6 feet under, they are found to be rather unmanageable, on account of their extra weight and length. The kerf for a 5 feet holing is about 14 inches in front, tapering down to 2 inches, and the kerfings are not necessarily all slack. When the miner has holed a certain depth he may retire his machine, and slice off round coal. In a seam of average hardness, a length of 80 feet of face will be holed to a depth of 5 feet in an 8 hours' shift. The weight of a complete coal-cutter is about 700 pounds for coal of average hardness, and 800 pounds for harder coal. The height averages 14 inches, and the width is 15 inches.

The whole of the coal at the First Pool mines, Pennsylvania, is worked with air-power punching-machines, and all the leading makes are used, namely:—the Ingersoll-Sergeant, the Harrison and the Sullivan. Mr. Dixon, the manager, has supplied the writer with the following information:—

In hand-holing, the present rate in the district is 2s. 8½d. (65 cents) per ton for cutting and loading, including the payment to the helper. Machine-cutting costs 6¼d. (12½ cents), and loading 1s. 6d. (36 cents), equivalent to a cost of 2s. 0¼d. (48½ cents) for machine-mining, compared with 2s. 8½d. (65 cents) for hand-holing, or a saving of 8d. per ton; but from this amount must be deducted ¼d. (¼ cent) per ton for sharpening tools, the cost of compressing the air, and interest on plant.

One machine, in a coal-seam 5 feet thick, and of average hardness, will produce 30 tons per shift of 10 hours. Consequently, a single shift of 10 hours for 5 days per week, and 50 weeks per year reckoning a saving of only 6d. per ton will shew a net gain of £187 10s., which is about equivalent to the cost of three machines. This saving does not include various other advantages with which the mining engineer is familiar, namely, more round coal, quicker development of a district, etc.

The average workmen could pay his helper, and earn from £16 to £17 (80 to 85 dollars) per month as against £9 to £10 (45 to 50 dollars) with hand labour.

The three leading pick-machines used in the United States o America are excellent machines, well constructed, of goo material, and are all working efficiently. The Sullivan machine however, possesses certain advantages which the writer wil endeavour to describe. The chief variations in the Sullivar machine are:—the valve-motion is positive, that is, the air i admitted direct to the piston on its forward and backward stroke and the admission can be regulated by the operator, the air act as a cushion to take the recoil of the blow instead of leathe cushions, there are fewer working parts, the cost of maintenanc is reduced, and the vibration is less, owing to the piston cushioning on air. The Sullivan machine is constructed to strike slow an hard, and it contains a regulator which controls the supply of ai as the pressure varies, so that the length and force of the blow i under control; all joints are scraped or ground, and the piston i made of nickel (or Harveyized) steel.

In common with machines of this class, the Sullivan may b mounted on large wheels so as to shear the coal close to the rib but a special shearing-machine is preferably employed.

Although 80 feet of holing to a depth of 5 feet in an 8 hour shift may not be considered comparable with the performanc of longwall machines, it must be recollected that the puncher i not a competitor but a valuable tool for heading in pillar-and-stal workings, and also in longwall workings where the nature of th coal, roof or floor, and position of timber make other machine inadmissible.

A vote of thanks was accorded to Mr. Davis for his paper.

The following paper was read by Mr. W. H. Hepplewhite, o "The Hepplewhite Tapered Pit-props and Bars":—

THE HEPPLEWHITE TAPERED PIT-PROPS AND BARS.*

By W. HUTTON HEPPLEWHITE, H.M. INSPECTOR OF MINES.

The destruction of wooden props, caused through breakage, when used in coal-mines, by the depression of the superincumbent strata, more especially in those mines having hard, impenetrable floors, is a serious item in the cost of coal-working. Anything that helps to obviate such destruction, consistent with the safety of the workmen employed, will be welcomed by colliery-owners whose timber-bills, resulting from the enormous quantity of props broken and rendered useless for re-setting, are very high.

It is a wellknown fact that in extracting a coal-seam of ordinary thickness, apart from the cost of so doing, the waste cannot be stowed so as to have the same solidity as that which it had before the extraction of the coal. It therefore follows that the roof inevitably must sink, more or less, according to the thickness of the seam and the nature of the superincumbent strata.

From numerous measurements which the writer has had the opportunity of taking in various coal-seams, he finds that the depression varies from 2 to 7 inches at a distance of 6 feet back from the coal-face. The roof of the Top Hard coal-seam has a subsidence of 1 inch per foot of distance from the face, generally throughout the district. This amount of depression is not surprising if we consider the large area of exposed waste where the longwall system of working is adopted. It is no unusual occurrence to have 6,000 feet, or even more, of working-face advancing simultaneously, under a weight of superincumbent strata many hundred feet thick.

Undoubtedly a heavy subsidence is quietly and imperceptibly taking place, and the wooden props commonly used in coal-mines are not strong enough to withstand the weight. Therefore they give way in the shape of either kneeing, buckling, or some other

* British patent, May 11th, 1899, No. 9,925.

form of breakage, rendering them of no further use as pit-props. It is usually found, where this depression takes place over a large area, that the roof over the broken props is not resting on them to any appreciable extent, simply because the superincumbent strata have settled down bodily, in spite of the props, to such an extent that locking or keying-together ensues, and the depression back in the waste continues at a much slower rate.

Some collieries use steel props and thick pieces of wood at the top and bottom, rarely allowing more than two rows of props to stand along the face. Others, again, have adopted extraordinarily thick wooden props. The writer has observed that, when steel props are used, and the wood at the top and bottom has been penetrated to the utmost limit, they begin to bore into the roof, which makes an opening, and probably gives a loose-end to a large piece of rock.

The circular issued by the Secretary of State on August 9th, 1899, to colliery proprietors, foreshadows legislation enforcing "systematic timbering" in coal-mines; and mines that have not already adopted some system of timbering, namely, the setting of props at the working-face at a stipulated distance apart, may find their timber-costs considerably augmented thereby.

The writer believes that he has to a great extent solved the problem of preventing the breakage of props, when used under ordinary normal conditions, by simply thinning or tapering one end of the prop, allowing it to yield to the sinking roof, so that, instead of the prop breaking, the tapered end will "burr" or "fuzz" up the taper. The writer anticipates that the thinning, or weakening, of one end of a prop will be regarded by some mining engineers as altogether opposed to the principle of safely supporting the roof of a working-place, especially by those who have adopted the use of steel or extraordinarily thick wooden props.

An endeavour will now be made to show how the tapered prop acts, when first set and during the subsequent stages. We will take a prop, 5 feet long and 6 inches in diameter at the thin end, and after tapering one end, use it in a pit in the ordinary course of working. Having previously ascertained that the normal depression of the roof is 6 inches, 6 feet back from the face, we calculate that the prop will require a taper 11 inches long, leaving the thin point 3 inches in diameter. Of course it must be under-

stood that these props were only intended for hard, impenetrable floors, exception being taken where a few inches only of soft clunch overlies a hard floor.

A prop so treated will probably sustain a dead weight of about 16 tons, before any appreciable impression is made on the tapered end. In time, the superincumbent strata over a certain area are quietly and imperceptibly settling. The smaller diameter of the tapered end of the prop will be observed to have begun to "burr" or "fuzz," and the greater the pressure the more will it advance along the taper to the ordinary thickness of the prop. When the time arrives for its withdrawal, the prop so treated will be found erect and sound, whilst an ordinary prop would have been broken in some shape or form.

After the withdrawal of the prop, supposing that the "burring" has advanced, say, 4 to 5 inches along the taper, it can be re-set in the same stall on a foot-lid, and the "burring" will proceed again on the same principle. In fact, it follows that so long as a weak point is made at the end of the prop, and rendered relatively weaker than the other portion, the prop may be re-set in suitable places as long as there is length to set. Finally, when too short for use as a prop, it can be cut up for lids or sleepers.

When props are set in a working-place to sustain the roof, immediately following a web of coal, they do not sustain the whole of the superincumbent strata, but merely a portion, varying from a few hundredweights in some mines to a few tons in others. The greatest breakage of props, according to the writer's observation, occurs 5 feet from the face and beyond.

The pecuniary advantage derived from the use of tapered props will be obvious to colliery-managers. At one large colliery, in which tapered props had been wholly in use for some months, the consumption of props had been reduced fully 25 per cent., and broken props had become a thing of the past.

When bars or stretchers are required upon roadways to support the roof, and the side pressure of such roadways is excessive, it is not unusual to see the timbers speedily broken somewhere near the centre, principally, and in most cases, wholly, owing to side pressure, and the original object for which they were set is nullified. Such timbers have to be re-set, and the cost of timber and of labour is doubled. Bars or stretchers having both ends treated

similarly to the props, the ends being relatively weaker than the middle portion, would "burr" or "fuzz," thus saving the timbers from breakage, and at the same time more securely supporting the roof.

The tapering can be done either by manual labour, machinery, or any other convenient method, and should not exceed in cost ½d. per prop.

An entire seam, or even a district, in which tapered props are used throughout is a gratifying sight, as compared with the use of the old form of prop. Every prop is standing erect and sound, firmly supporting the roof, and props that have been re-set three times do not show a splinter. No prop will be found to have pierced through the lid and to have penetrated the roof; and consequently there is not a single break in the roof throughout a district, which has settled down to its natural subsidence. Such evidence proves that props set to support the working-places with a weak point, such point forming a cushion, will allow the roof to find its natural depression without breaking into it. The workmen are in greater security, and the props are more easily withdrawn.

The accompanying drawings (Plates I. and II.) represent ordinary props and tapered props, when used under exactly similar conditions, and nearly all the figures have been reproduced from actual specimens. Each setting is supposed to last 14 days, the average length of time occupied in loading a web of coal out of a stall, and in moving forward the props. The value of the original prop is based on present-day prices, and after each re-set a proportionate value for loss of length has been deducted, although in reality the value of each set to the owners would be the same, namely, 10½d.

Fig. 1 (Plate I.) represents a fir-wood pit-prop, 6 feet long, and 6 inches in diameter, with a taper at one end of 11 inches, and the thin point, 3 inches in diameter. Fig. 2 (Plate I.) shows the length of taper destroyed by "burring," and after the prop is trimmed with an axe it can be re-set in a suitable place.

Fig. 3 (Plate I.) shows an ordinary prop "buckled," and rendered useless for re-setting, but it can be utilized for lids, as shown in Fig. 4.

Figs. 5, 6 and 7 (Plate I.) represent a tapered prop, and three settings, foot-lids being used to retain them for use in the same

working-place. The writer does not advocate the general use of foot-lids, especially in the shape of broken pieces of timber with an uneven surface. Lids, when used, should be made especially for the purpose, and should not be of a less breadth than the props, and if this requirement be attended to, the lids would then form an essential part of the prop.

Fig. 8 (Plate I.) shows a prop sheared at a point about 1 foot from the top, and when the sheared part is sawn off, it can be cut into sleepers or lids, as shewn in Fig. 9 (Plate I.).

Figs. 10, 11, 12 and 13 (Plate I.) represent a tapered prop set four times in the same working-place, and it could then be sent out of the pit and re-tapered for use in a thinner seam.

Fig. 14 (Plate I.) represents an ordinary prop; and after being set twice, it is crushed and sheared as shewn in Fig. 15 (Plate I.), and is then useless except for building into a corner chock (Fig. 16, Plate I.).

Fig. 17 (Plate I.) shows an ordinary larch bar let into the sides of a packed roadway to sustain the roof; and side pressure eventually produces the result shown in Fig. 18 (Plate I.). Fig. 19 (Plate I.) represents the same kind of bar with both ends tapered, and the result, when the side pressure operates on the ends, is shewn in Fig. 20 (Plate I.). An expensive bar is thus saved from breakage, and the roof is securely held.

Fig. 21 (Plate II.) shows an ordinary larch bar with two fir-wood props set on a packed roadway; and Fig. 22 (Plate II.) shews the result after both top and side pressures have played their part. Fig. 23 (Plate II.) shews the use of tapered bars and props and Fig. 24 (Plate II.) proves the resulting safety of the method.

Fig. 25 (Plate II.) exhibits the history of a tapered prop, and how it may be made serviceable when carefully looked after. This experiment was actually carried out at the Pemberton collieries, Lancashire, and the writer is indebted to Mr. Ernest Douglas who has established that repeated setting of the same prop does not materially weaken its strength.

The machine for tapering props (Fig. 26, Plate II.), is fitted with removable knives. It has a travelling table, similar to the table on a pipe-screwing machine, controlled by a rack-and-pinion. The prop is secured to this table by a cramp, with right-and-left-hand screws. Each machine will taper about 30 props per hour, and about 4 horsepower is required to drive it.

Table I. records the results of the writer's measurements of the depression of the roof at several collieries and in different coal-seams. A stall, working on the longwall system, was selected with a level roof, which is a true indication there had been no abnormal weighting of the superincumbent strata; then as near as practicable to the coal-face, the height from the floor to the roof was measured; then the heights at distances of 6 feet,

TABLE I.—SHOWING THE DEPRESSION OF THE ROOF IN SEVERAL COAL-SEAMS.

No. Representing the Name of the Mine.	Place of Measurement.	Depression of Roof at Various Distances from Face.		
		6 Feet.	9 Feet.	12 Feet.
	TOP HARD COAL-SEAM—	Inches.	Inches.	Inches.
1	Gate-end	4½	6¾	9½
2	do. ...	5	8	10
3	do. ...	7½	8½	10
,,	At new buttock	2½*	—	—
,,	Across waste	5¼*	—	—
4	Gate-end ...	4½	8½	—
,,	At new buttock	3½*	5½*	—
5	Gate-end ...	5	8	—
6	do. ...	6	9	10
7	Across waste	3*	5*	7*
8	do.	4¾*	7¾*	—
9	do.	5¼*	—	—
10	Gate-end ...	6¾	—	—
11	At new buttock	2½*	—	—
12	do.	2¾*	—	—
13	Gate-end ...	6	—	9½
14	Across waste	3*	—	—
	Average depression ...	5·66	8·12	9·85

No. Representing the Name of the Mine.	Place of Measurement.	Depression of Roof at Various Distances from Face.	
		6 Feet.	9 Feet.
	LOW MAIN COAL-SEAM—	Inches.	Inches.
1	Gate-end ...	3¼	6
2	At new buttock	3½	—
3	Pack-end ...	3½	—
,,	At new buttock	2¾	—
4	do.	2¾	—
5	Gate-end ...	3¾	6¼
6	do. ...	4	6¾
7	do. ...	3	5
8	do. ...	4¾	6¾
	Average depression ...	3·44	6·25
	DEEP SOFT COAL-SEAM—		
1	At new buttock	2½	4
2	do.	2	—
,,	Gate-end ...	3	5
3	do. ...	3¼	—
	Average depression ...	2·69	4·50

* Excluded in calculating the average depression.

9 feet and 12 feet back into the waste or gate-road were similarly measured and thus one obtained the actual depression of the roof when working the coal under normal conditions. The average depression at 6 feet back from the face, varied from 2·69 inches in the Deep Soft coal-seam to 5·66 inches in the Top Hard coal-seam, and the observations varied between 2 inches and 7½ inches.

Table II. records the costs or values of each prop shewn in the illustrations (Figs. 1 to 15, Plate I.).

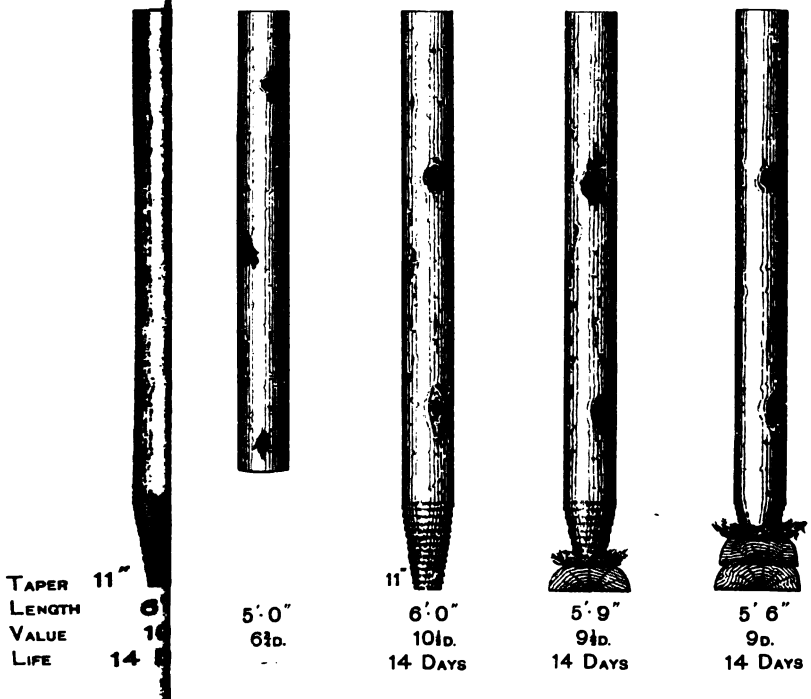
TABLE II.—SHOWING THE COMPARATIVE VALUES OF TAPERED AND ORDINARY FIR-WOOD PROPS, 6 FEET LONG AND COSTING 10½D. EACH.

Number.		Tapered Props.				Ordinary Props.			
		Plate I.	Length of Prop.	Value of Prop, &c.	Life.	Plate I.	Length of Prop.	Value of Prop, &c.	Life.
		Fig.	Ft. Ins.	s. d.	Weeks.	Fig.	Ft. Ins.	s. d.	Weeks.
1	Settings:								
	First ...	1	6 0	0 10½	2	3	6 0	0 10½	2
	Second ...	2	5 3	0 7¼	2	—	—	—	—
	Lids	—	—	0 6	—	4	2 8	0 6	—
	Fire-wood ...	—	—	—	—	—	—	0 1	—
	Totals ...	—	—	1 11¾	4	—	—	1 5½	2
2	Settings:								
	First ...	5	6 0	0 10½	2	8	6 0	0 10½	2
	Second ...	6	5 7	0 9¼	2	—	—	—	—
	Third ...	7	5 4	0 8	2	—	—	—	—
	Lids	—	—	0 6	—	—	—	—	—
	Sleepers, &c.	—	—	—	—	9	5 0	0 6¾	—
	Totals ...	—	—	2 9¾	6	—	—	1 5¼	2
3	Settings:								
	First ...	10	6 0	0 10½	2	14	6 0	0 10½	2
	Second ...	11	5 9	0 9½	2	15	5 9	0 9½	2
	Third ...	12	5 6	0 9	2	—	—	—	—
	Fourth ...	13	5 3	0 7¼	2	—	—	—	—
	Lids	—	—	0 6	—	—	—	—	—
	Totals ...	—	—	3 6¼	8	—	—	1 8	4

Table III. has been prepared from Table II. and shows that the estimated saving, which may be anticipated, by using tapered props exceeds 50 per cent.

TABLE III.—SHOWING THE PERCENTAGE SAVINGS OBTAINED BY THE USE OF TAPERED FIR-WOOD PROPS, 6 FEET LONG AND COSTING 10½D. EACH.

No.	Cost of Prop after deducting the Value of the Wood used as Lids and Sleepers.	Life.	Cost per Prop per Week.			Saving obtained by the Use of Tapered Props.
			Tapered Props.	Ordinary Props.		
				Sheared.	Buckled.	
	Pence.	Weeks	Pence.	Pence.	Pence.	Per cent.
1	4½	4	1·125	—	—	—
	4½	2	—	—	2·500	50
2	4½	6	0·750	—	—	—
	3¾	2	—	1·875	—	60
3	4½	8	0·562	—	—	—
	10½	4	—	—	2·625	78



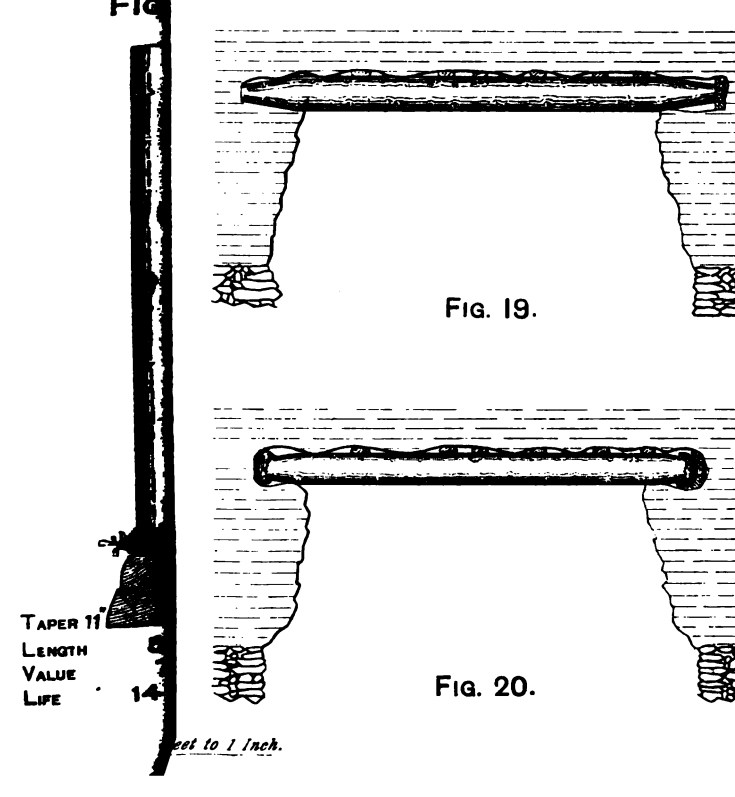
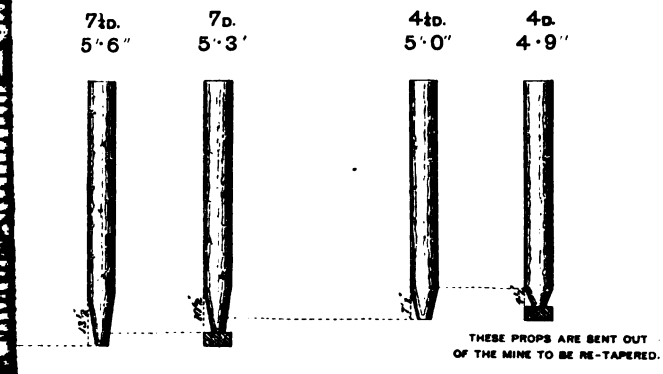


Fig. 19.

Fig. 20.

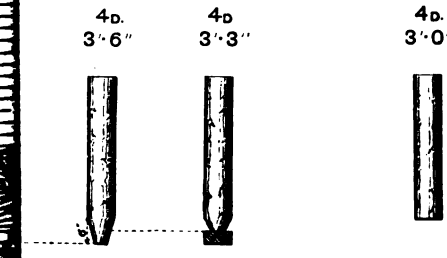
…eet to 1 Inch.

5.



…ING AND ORRELL FIVE FEET MINES.

PEMBERTON FOUR-FEET MINE.

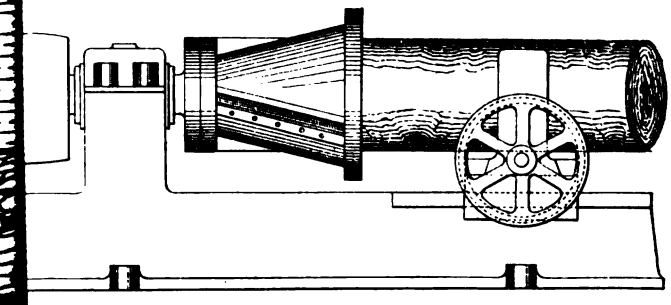


Scale, 4 Feet to 1 Inch.

ORRELL FOUR-FEET MINE.

ORRELL FOUR-FEET MINE.

FIG. 26.



MACHINE FOR TAPERING PIT-PROPS.

Scale, 1 Foot to 1 Inch.

The results recorded in Table IV. have been obtained from colliery, in which the tapered props have been in use throughou the workings in the Top Hard coal-seam for several month and the figures have been derived by noting the consumption i each case.

TABLE IV.—SHOWING THE SAVING EFFECTED AT A COLLIERY USING FIR-WOOD PROPS, 5 FEET AND OVER IN LENGTH AND COSTING 10¾D. EACH.

	Tapered Props.	Ordinary Props.	
		Sheared.	Buckled.
Life ... ... Weeks	6	4	2
Cost per prop per week ... Pence	1·79	2·687	5·375
Gain by using tapered props ... Per cent.	—	33	66

The CHAIRMAN said he must confess that this paper came t him quite as a revelation. If, as Mr. Hepplewhite contended there were such immense advantages in merely tapering the end of the props, how was it that they had never found it out before

Mr. G. SPENCER (Mapperley Collieries) said that for the pas twelve months he had been using tubular steel props, and h found that these steel props cut into the roof when the floor wa harder than the roof, and prevented that subsidence which wa absolutely necessary, so as to maintain the evenness of the roo It was impossible to support the superincumbent strata so as t prevent them, as a whole from settling. The function of the face props was to support the local weights and nothing more. Th pack-walls and gobbing should support the ground-weight, an be of the same strength as the original strata, after compressior A perfect prop would be a spring of sufficient strength to suppor the local weight. He had proved the value of tapered props i several stalls in the Kilburn coal-seam, which had a hard top an a hard floor, and he could confirm the accuracy of all Mr. Hepple white's statements. The props were 5 feet long. He considere that Mr. Hepplewhite's invention was a valuable one, and believe that it would cause a revolution in mine-timbering.

Mr. H. STEVENSON (Pinxton) said that he had used prop crowned at both ends, set upon foot-blocks, which reduced th cost of timbering by 50 per cent.; and he had also tried tapere props. In the Blackshale seam, they had been set 10 times with

out being broken, as against ordinary props being set 6 times. In other seams, the tapered props could be set from 3 to 6 times, while the ordinary prop would be broken by the third setting. He had tried the tapered props in four seams, and so far they had uniformly given good results.

Mr. W. Hay (Shirebrook Colliery) said that he had seen several tapered props in a large colliery in Derbyshire, where they had been in use for some months. The stallman said that he would not like to be without them, as the stall did not require the same amount of timber, and there was less trouble to get the props out. He (Mr. Hay) tried them at Shirebrook colliery, and had now been using them for 2 months with the results stated in the paper. He had set the tapered props 3 to 4 times, and then had cut them into sleepers. The seam had a hard floor and a soft roof.

Mr. J. H. W. Laverick said that he had had no experience of tapered props, beyond what they called "crowning," which was an old system, and was probably the one to which Mr. Stevenson referred. It was always imagined that a great saving had resulted from adopting that system of "crowning." When the tapered props became shortened, he understood that Mr. Hepplewhite would use extra lids at the bottom, and again use the props in the same seam. He would like Mr. Hepplewhite to state how many lids he considered it would be advisable to use at either the top or the bottom of the props for that purpose.

Mr. A. S. Douglas observed that he had used tapered props for about 5 months, generally throughout an entire colliery, and he must confess that at the commencement he was somewhat sceptical as to the result. He believed that the first tapered prop he used (and the only one as it turned out) was broken like Fig. 3 (Plate I.), but he found on removing the *débris* that the prop had bored its way into the floor, and was so bound round the bottom that it had no opportunity of "burring." Out of some 1,500 props used weekly, that was the only prop he had seen which had "buckled." The consumption had been reduced from 348 props down to 287 props a day, and that represented a saving, after allowing for the average cost of tapering at ½d. per prop, of something like £505 per annum. He had not yet fully adopted the use of tapered bars in the roads, but he was gradually introducing

them, and they were acting in the same way, so that the £505 would really form only part of the saving. Prof. Louis had stated that a prop that had been drawn after having been set was decidedly weaker than when originally set.* Prof. Louis had tested a prop up to 34 tons, and after it had been in use he tested it again, and found that it would not bear the same amount of weight, and so he said that it had been weakened. But that statement would not apply in the case of a tapered prop: the weight would perhaps be 15 tons to start with, and as the taper wore away, its resistance would increase until the whole of the taper was removed, and the maximum strength of the original prop would be reached. Care should be taken, so that a prop before the taper was entirely removed should be sent to bank, and re-sharpened for use in a part of the mine where shorter props were used, and they would thus avoid broken props. An engineer went down the colliery with him looking for broken props, but although the search occupied about 4 hours they were unable to find one. He did not think that lids should be used beyond 8 or 9 inches in thickness. Where tapered props were used, they would find that the lids were less damaged by pressure than would be the case if set on an ordinary square-ended prop. He had spoken at some length on this question, because he had fully tested the tapered props, and had certainly derived considerable advantage from their use. The workmen liked them—the coal worked better owing to the roof-weight settling more evenly on the face—they had not to bring the same amount of timber into the stalls, and there were no broken props cut out and re-set. He felt sure from his experience that they were the props of the future. It should be, however, always remembered that if broken props were to be avoided there must be as much taper on the prop when set as the distance down which the roof would lower during the time that the prop was required to stand. This length should be determined by periodical measurements, as very considerable variation existed even in the various districts of the same colliery.

Mr. A. H. Stokes (H.M. Inspector of Mines) understood that Mr. Douglas did not mean that there would be less safety by setting less timber—but that the same number of props should be set as before, although they could re-set them more times. The

* *Trans. Inst. M. E.*, vol. xv., page 352.

number of standing props should not be reduced. Steel props should never be set without lids at both top and bottom. It was desirable for a wooden prop to fail at the bottom, like Fig. 2, rather than in the middle like Fig. 3 (Plate I.). There should be a limit to the shortening of wooden props and making up of the length by the use of lids placed on the top of each other.

Mr. G. Elmsley Coke (Nottingham) asked Mr. Douglas whether tapered props affected the weight on the coal-face and the getting of the coal.

Mr. A. S. Douglas replied that with tapered props the weight was more evenly thrown upon the face. There were now no falls in the benks or stalls such as used to occur occasionally, and this showed that the weight was thrown more regularly upon the coal-face.

Mr. H. R. Hewitt said that he had not had the privilege of seeing any of the shaped timber in actual use, but he could understand that the prop was more serviceable from an economic point of view if it behaved as the author stated. The actual breaking-weight would be less than with a whole prop, and it was a question whether it was advisable to use a prop with a reduced breaking-weight, when more strength might be had with the uncut timber. Could Mr. Hepplewhite give the members the actual breaking-weight of two props from the same stock and of the same length and diameter, one of the ordinary kind, and the other shaped at the ends as described in the paper? For bars or stretchers (placed for the protection of roads against side pressure) this cutting of the timber should be of some use, the strength of the bar or stretcher not being weakened thereby, the ends could show the progress of the lateral pressure, and the timber would be in use a much longer time than if it had been set whole. Accidents did not occur through props and bars breaking, but rather from the timber being pushed out by pressure, or through the failure to set a sufficient number.

The Chairman (Mr. M. H. Mills) said that it would be interesting to have tests made as to the strength of the prop in its ordinary condition, and the strength of the prop when tapered. It would be a dangerous thing to do too much tapering with a short roof, as a very heavy fall might occur by reducing the strength of their

props. He intended to try tapered props, but he would take very great care as to the places in which they would be used.

Mr. A. S. Douglas explained that he had tested 6 of each kind of prop in the hydraulic testing-machine at the Nottingham University College. In each case a lid was used at the top: with a pressure of 7 tons the lid began to crack; at 15½ tons "fuzzing" began, and was maintained for a length of 3 to 6¼ inches while the prop was crushed down; and a pressure of 34 tons was used before the whole of the taper was worn off. The prop therefore carried a pressure of 15½ tons, increasing to 34 tons, before it would break like an ordinary prop. An ordinary prop, 5 feet long and 5 inches in diameter at the small end, was broken with a pressure of 35 tons.

Mr. W. H. Hepplewhite, replying to the discussion, showed a photograph of a group of props tested by Prof. Robinson, of University College, Nottingham. The props tested were 58 inches long, and about 5 inches in diameter at the small end, with flat ends. The tapering was about 14 inches long, and the point was 3 inches in diameter. The prop was tested in an upright position, with one end resting on thin sheet-cardboard, and the other one on a lid 1·35 inches thick. The load was slowly and gradually applied, and the shortening or yielding was noted as well as the breaking-load. Ordinary props broke with a weight varying from 29·05 to 37·50 tons, and the tapered props began to show signs of "burring" with a weight of 15·54 tons. One prop, after a length of 7 inches had been sawn off the "burred" end, again began to "burr" with a weight of 26·40 tons. The whole of the "burred" end was then sawn off, the length of prop being reduced to 36 inches. This shortened prop was again placed in the testing-machine, and yielded with a central fracture, crushing with a weight of 34·50 tons, and a shortening of ¾ inch. No appreciable impression was made on one of the tapered props, until a weight of 15·40 tons was reached. They found that 14 inches was too much taper for a prop 58 inches long, and had the taper been only 9 inches, he had no doubt that it would have stood a weight of more than 15 tons. From these experiments, it would appear that, although being under pressure twice with tapered ends, the prop had not been weakened to any appreciable extent, and for practical purposes was as strong as when first placed under the test.

The two lids shown under the "burred" prop in Fig. 7 (Plate I.) were only 4 inches thick or 8 inches altogether. The lids shown in Fig. 13 were 9 inches thick in all. He did not object to the use of two lids under a prop, provided that they were no less in breadth than the diameter of the prop, and when this occurred only one lid should be used on the top. It was not unusual to see pieces of bind or clunch with uneven surfaces put under props of greater thickness than that. The lids should be of good solid wood, not partly worn out, and they should not be of less breadth than the diameter of the prop.

A vote of thanks was accorded to Mr. Hepplewhite for bringing this most interesting and valuable discovery before the members.

The further discussion of the paper was adjourned.

Mr. B. McLaren read the following paper on "Preventible Colliery Fatalities":—

PREVENTIBLE COLLIERY FATALITIES.

By B. McLAREN.

(1) Introduction.

The first object at collieries should be the lessening of accidents to the persons employed, and with the object of considering colliery-fatalities which might be prevented, the writer has compiled several tables of statistics. On referring to Table I., it will be seen, when the three years 1896-98 are compared with the period 1876-78, that the average death-rate from accidents per 1,000 persons employed under-ground, under the Coal-mines Regulation Act, in the United Kingdom, has decreased 45 per cent., while above-ground the decrease is 15 per cent., and the two together show a decrease of 43 per cent.

Table II. shows that for the period 1896-98 the average weight of minerals drawn per life lost was 223,203 tons, compared with 124,791 tons in the period 1876-78, or an increase of 79 per cent., and although this remarkable and praiseworthy achievement has been brought about by many agencies, it will be admitted that there may be need and room for yet greater improvement. When we moreover reflect on the very large number of accidents, which, though not proving fatal, result in injury to the spine, loss of some faculties, limbs, etc., and the still greater number of cases of temporary injuries, such reflections must induce mining engineers to continue the endeavour to bring about further improvement.

Table I. also shows that for the three years 1896-98 the average death-rate from accidents per 1,000 persons employed under-ground was:—From explosion of fire-damp and coal-dust, 0·14; from falls of ground, 0·79; in shafts, 0·11; from miscellaneous causes, 0·45; and from all causes under-ground, 1·49. From all causes above-ground the death-rate was 0·84; and from under-ground and above-ground accidents combined, 1·36. Compared with the averages for the three years ending 1878, these figures show that from explosions, falls of ground, in shafts, all causes under-ground, on the surface, and altogether, there are decreases

of 83, 31, 64, 45, 15 and 43 per cent. respectively, while there is an increase of 7 per cent. from miscellaneous under-ground accidents.

A careful and impartial consideration of the particulars of each fatal accident, as given in the reports of H.M. inspectors of mines, leads the writer to the conclusion that the number of fatal accidents, under the various headings, which might have been prevented in each district, during the years 1896-97-98, with the average per year, are as shown in Table III.

It will be seen from Table III. that the percentages of preventible fatalities were:—Explosions, 39; falls of ground, 25; in shafts, 74; miscellaneous under-ground, 41: total under-ground, 35; on the surface, 52; and under-ground and above-ground together, 37. In coming to this conclusion, the writer has included all fatalities stated to have been brought about by carelessness or neglect; those in which a deficiency of props, sprags, bars, chocks, packs, etc., are mentioned; cases of want of judgment; a moment's forgetfulness on the part of some one; acts contrary to the Coal-mines Regulation Act, Special Rules, and ordinary regulations; want of care, etc.; and those which present themselves as possibly preventible; while all apparently doubtful cases are omitted. The methods of preventing the accidents were known at the time of their occurrence, or would be adopted to prevent similar fatalities from recurring. In the case of those accidents deemed preventible under the heading of explosions of gas or coal-dust, no accidents have been included which would be prevented by the abolition of the use of naked lights in coal-mines.

A consideration of the causes, as far as they can be ascertained, leading to the preventible fatalities, with suggestions as to their prevention, may obviate the occurrence of like accidents in the future.

The various ways in which the preventible fatal accidents might have been averted during the 3 years 1896-98 are analysed under various headings in Table IV. The probable means of their prevention are as follows:—

(2) Explosions of Fire-Damp and Coal-Dust.

(*a*) *Carrying out the Coal-mines Regulation Act, Special Rules or Regulations* (58 fatalities or 67 per cent. of the total).—In the

most serious case 20 lives were lost by the use of gunpowder on a main haulage-road, for an unknown and apparently unnecessary purpose, the explosive being used without consent, and contrary to the regulations of the mine. Of the 58 deaths, 15 deaths (13 accidents) arose through persons entering with naked lights into unexamined disused workings containing fire-damp; 5 deaths (1 accident) by a fireman unlawfully opening a safety-lamp and firing gas; 4 deaths (1 accident) through using gunpowder instead of a permitted explosive in a dry and dusty place which was not watered; 3 deaths (1 accident) caused by an unauthorized person firing a shot in a dry and dusty section, producing gas; 2 deaths (1 accident) by an under-manager and others "firing a charge of gunpowder in gas to break it up"; 1 by a fireman lighting the fuze of a carbonite-shot in an accumulation of gas, etc.

(*b*) *Examining with or using Safety-lamps where Gas might be expected* (16 fatalities or 18 per cent.).—Five deaths (5 accidents) occurred through persons entering their places to commence work with naked lights; 3 deaths (1 accident) by persons entering their working-place with naked lights after taking a meal; and 1 death by going into his working-place with a naked light ½ hour after firing a shot.

As many of these accidents took place in mines believed to be free from fire-damp, the writer suggests that in all coal-mines in which naked lights are used, safety-lamps should be employed for making the first examination, as also when persons enter places after a cessation of work and after firing a shot, etc., and also at all places where fire-damp, though previously unknown, might show itself, as at faults, fissures, dykes, etc.

(*c*) *More Care* (12 deaths or 15 per cent.).—Seven deaths (1 accident) were brought about by the firemen of a mine using unbonnetted safety-lamps, one of which ignited gas; 1 death "by using naked lights where more or less serious explosions had occurred"; 1 death was due to the position of one level in relation to another not being sufficiently known, a man holed through and fired gas; 1 death to opening out a seam of suspicious character in longwall, with naked lights, etc.

(3) Falls of Ground.

(*a*) *Setting more Timber such as Props, Bars, Chocks, etc.* (154 deaths or 46 per cent.).—In some instances, the persons who lost

their lives had been ordered to set more timber, for their protection, but had not done so.

(*b*) *Setting Coal or Clod Sprags or taking down Clod* (70 deaths or 21 per cent.).—This like the last precaution is a matter requiring great watchfulness in some mines; notwithstanding that ample provision is made in the General and Special Rules for setting sprags wherever required. It is deplorable that officials do not receive more support than has sometimes been meted to them, when they have proceeded against men for not carrying out this rule, *e.g.*, Mr. J. S. Martin, H.M. inspector of mines for the South-western mines-inspection district, in his report for 1894, referring to a case recently before the stipendiary magistrate at Merthyr, says "practically he decided . . . that the colliers, and not the officials, were the judges, and that because the coal had not fallen for two days, the action of the collier in not setting sprags was justifiable. . . . This decision, being subversive of all authority and discipline in mines, will do much harm, especially in the district in which it was promulgated."* It is noteworthy that 28 per cent. of the preventible fatal accidents from falls of ground, in the South-western mines-inspection district, are due to want of sprags being set.

(*c*) *More Care* (41 deaths or 12 per cent.).—Four deaths (4 accidents) were due to falls of stone which ought to have been taken down; 3 deaths (3 accidents) of persons going under bad stone when there was no necessity for doing so; 2 deaths (2 accidents), likewise before the stone was examined and put right: 1 death through ripping the gate-lip, too far in advance of the packs; 1 death was due to a fall, caused by a rail which was improperly fixed on a tub knocking out a prop; 1 death was due to undermining a prop while cleaning a water-level; 1 death to undermining props while lowering way; 1 death to an improper examination by a deputy; 1 death to an insufficiency of firemen; etc.

(*d*) *Using a Ringer-and-chain instead of a Hammer or Pick for drawing Props, Bars, Sprags, etc.* (38 deaths or 12 per cent.)—In the Midland mines-inspection district 11 deaths, or 39 per cent. of the total number of the preventible fatalities, are due to falls of ground.

(*e*) *Carrying out the Coal-mines Regulation Act, Rules or Regulations* (33 deaths or 9 per cent.).—Six persons (5 accidents)

* Page 3.

lost their lives by falls of stone where men had been ordered to take down stone, but had neglected to do so; 4 deaths (4 accidents) from falls of coal while working where men were forbidden to work; 2 deputies (2 accidents) lost their lives while alone drawing timber; 1 man was ordered to set a prop, but did not do so; 1 death was due to a fall of overhanging coal, which ought to have been spragged sooner; and 1 boy commenced to work at the face before the miner had examined it.

(4) Accidents in Shafts.

(*a*) *More Care* (40 deaths or 29 per cent.).—One man was killed by a tram falling on him down a sinking-pit, caused by a banksman fastening it with a loose wedge, which came out; 1 man was killed in a sinking-pit, through a banksman running a kibble too quickly on to a scaffold; an air-pipe improperly lashed fell down a shaft, killing 1 man; 1 man was crushed while getting into a cage, by the negligence of the banksman; 1 man was crushed by the cage while cleaning the sump: he knew the cage was descending, but did not get out of its way; and 1 death arose through an engineman starting the cage while a tram was being put in.

(*b*) *Carrying out the Coal-mines Regulation Act, Rules or Regulations* (27 deaths or 20 per cent.).—Five deaths (5 accidents) arose by attempting to get into a moving cage; 3 deaths (3 accidents) by the cage being moved without a signal; a manager was killed by getting on to a rope-ladder in a blind-pit, and the rope broke—he knew that the rope was bad; 1 sinker was killed by riding direct from the pit-bottom without first having the loop steadied; 1 sinker was killed through being overwound, there being no indicator on the winding-engine; 2 deaths (2 accidents) while men, contrary to Special Rules, were riding in the shaft with timber or rails unlashed; 1 death by attempting to go down the pit without the banksman being there, and the man got crushed, etc.

(*c*) *Adequate Cage-end Guards when Persons are in Cages* (18 deaths or 13 per cent.).—Assuming that in none of these cases the person had a fit from which he died, or was struck fatally by something, the writer thinks that these 18 lives might have been saved. The writer uses on each end of the cages suitable guards, of various sizes, some about 19 inches high (made of thin steel bars) weighing 14 to 21 lbs.; they are easily, quickly, and firmly

fixed on the ends of the cage, by the banksman or onsetter, at a height of about 24 inches above the floor.

In 1896, a fireman and an injured miner were ascending a shaft, and they both fell out and were killed; Mr. W. N. Atkinson, H.M. inspector of mines, in his report stated that "a bar placed across the end of the cage, such as is used in some cases when men are in the cage, might have prevented this accident."* In 1899, at a colliery under the writer's charge, while a cage full of men was descending a man at the end of the cage was suddenly hit in the eye by something, was completely overcome, immediately let go his hold on the handrail, and fell against the cage-end guard. In reporting this accident, the workman said that "but for the guard on the end of the cage I should have fallen out, and have been killed."

(*d*) *Suspensory Detaching-hooks and Safety-props* (17 deaths or 12 per cent.).—Considering the hundreds of thousands of persons frequently descending and ascending the shafts, with so few accidents, the greatest praise must be awarded to the care and thoughtfulness of winding-enginemen and others having charge of machinery. Nevertheless, the use of suspensory detaching-hooks and safety-props would be an additional safeguard: they might in some instances save lives, and, perhaps, in other cases, might save property and serious stoppages.

(*e*) *Shaft-belts when doing Shaft-work* (14 deaths or 9 per cent.).—Some men have an aversion to using these useful adjuncts, but the writer prefers to have them used in all cases of shaft-work, where it is possible and convenient to do so. Mr. W. N. Atkinson, H.M. inspector of mines, in his report for 1897, referring to an accident where an engineer was killed by falling off the cage, stated that "the use of a safety belt might have saved his life, but these are little employed;"† in his report for 1898, he refers to the death of a shaft-man who fell off a stay on which he was sitting, nailing some brattice-cloth on to a garland-curb, and whose life might have been saved by using such a belt attached to some holdfast.

(*f*) *Cage at Rest at Pit-top or other Landing before Pushing the Tub Forward* (13 deaths or 9 per cent.).—About 37 per cent. of the preventible shaft fatalities in the Eastern Scotland mines-inspection district arose through neglect to enforce this precaution.

* Page 12. † Page 12.

(*g*) *Not Walking across the Shaft-bottom or Staple-bottom* (6 deaths or 4 per cent.).—In the words of Mr. A. H. Stokes, H.M. inspector of mines, "such recklessness sooner or later is sure to lead to an accident."*

(*h*) *Adequate Self-acting Tub-controllers on Shaft-sidings* (3 deaths or 2 per cent.).—These fatalities arose through persons being knocked into the pit-bottom by "unscotched" trams following those that they were pushing. A self-acting tub-controller allows 1, 2 or more tubs (as it is constructed) to pass, then it holds the remainder back automatically.

(*i*) *Testing Ropes used in Wet or Warm Shafts for Torsion* (3 deaths or 2 per cent.).—Three deaths occurred in 2 accidents. The ropes, after breaking, were tested, and gave good results as to the breaking-strain, but very poor results when tested for torsion. In one case, steam-pipes in the shaft caused it to be warm and moist.

(5) Miscellaneous Under-ground Accidents.

(*a*) *Carrying out the Coal-mines Regulation Act, Rules or Regulations* (188 deaths or 58 per cent.).—Thirty-two deaths (32 accidents) were caused by riding on full sets where not allowed; 18 deaths (18 accidents) by going in front of tubs; 12 deaths (12 accidents) by riding on cranks, which is not allowed; 11 deaths (10 accidents) by riding on empty sets of tubs, which is not allowed; 8 deaths (8 accidents) by not setting stop-blocks on the top of inclines; 6 deaths (6 accidents) by riding on chains of sets; 4 deaths (4 accidents) by riding on tubs against regulations; 3 deaths (1 accident) by failure to keep bore-holes against water; 3 deaths (3 accidents) by breakage of jig-props, inefficient machinery; 3 deaths (3 accidents) by oiling machinery while in motion; 2 deaths (2 accidents) by sleeping on the rails in the pit, and full sets of tubs ran over them; 2 deaths (2 accidents) by charging shot-holes too small for the gunpowder-charge; 1 death arose from not going into the refuge-hole after lighting a shot; 1 overman sacrificed his life in an attempt to remove a large quantity of gas, when alone, etc.

(*b*) *More Care* (103 deaths or 32 per cent.).—Six deaths (1 accident) occurred by rupture of a valve or dam under a head of water; 6 persons (1 accident) were drowned by an influx of water from an adjoining colliery; 6 deaths (6 accidents) were caused by

* Annual Report for 1898, page 11.

careless handling of powder; 5 deaths (5 accidents) by incline-top lads allowing uncoupled tubs to run over the tops of inclines; 1 man fired a shot in his place, it burst through into an adjoining place, which the manager was examining, and killed him; 2 deaths (2 accidents) arose from drilling holes into missed carbonite-shots containing detonators; 3 deaths (3 accidents) were due to incautiously striking the detonators of miss-fires; 4 deaths (4 accidents) to travelling on the engine-planes, and being run over by the trains; 3 deaths (2 accidents) to ramming shot-holes with frozen gelignite; a pony put his foot on a broken sleeper, which tilted up and stuck into the putter's body; and 1 death was caused by a miner firing a battery while the deputy was at the face, and the deputy was killed.

(*c*) *Not travelling on Engine-planes while Endless-rope Sets of Tubs are in Motion* (17 deaths or 6 per cent.).—In some of these instances separate travelling-ways were provided, and they ought to have been used.

(*d*) *Improved Methods of Shot-firing* (14 deaths or 4 per cent.).—Seven deaths (7 accidents) occurred through lighting squibs instead of matches; 4 deaths (4 accidents) by lighting two shots at once by fuze, one went off, a man, thinking the other had not lighted, went up to it, when it exploded and killed him; a charge of dynamite was exploded, it ignited the fuze of a gun-powder-shot, and a man was returning to light the latter when it exploded, killing him.

(6) Accidents on the Surface.

(*a*) *More Care* (93 deaths or 51 per cent.).—Seven deaths (7 accidents) were caused by being jammed between pillars and waggons for want of space; 6 deaths (6 accidents) by being run down by empty waggons or locomotives while crossing sidings, and in some instances the victims were not properly warned by the watchmen, locomotive-drivers, etc.; 4 deaths (4 accidents) by being jammed between the buffers of waggons; 3 deaths (3 accidents) of daubers at coke-ovens occurred while getting daub at clay-banks, by its falling upon them; 2 deaths (2 accidents) by being crushed between waggons while crossing the rails near the pit; 1 man fell through a hole on the pit-bank while repairs were going on; and owing to a railway-crossing being out of repair a truck

got off the way and fatally crushed 1 man. In some cases, it might be advisable to erect bridges at crossings, to remove the risk to persons from waggons in motion.

(*b*) *Carrying out the Coal-mines Regulation Act, Rules or Regulations* (89 deaths or 49 per cent.).—Twelve deaths (12 accidents) were due to unspragged waggons gradually following after those being lowered down, and crushing the man in attendance; 11 deaths (11 accidents) were caused by attempting to sprag waggons with pit-props, brake-sticks or planks; 6 deaths (6 accidents) by oiling or being otherwise busy with machinery while in motion; 4 deaths (4 accidents) by not using coupling-poles for coupling and uncoupling waggons; 3 deaths (3 accidents) by attempting to jump on to moving trains; 3 deaths (3 accidents) of boys under age by moving waggons; 1 death while riding on a brake-lever in front of a waggon; 1 death by riding on a shunting-stick, and being thrown under waggons; 4 deaths (1 accident), caused by the bursting of a boiler at a small colliery: the plates were afterwards found to be of the thickness of brown paper.

(7) Summary.

According to Table IV., during the three years 1896-98, by carrying out the Coal-mines Regulation Act, Rules and Regulations, 395 lives might have been saved, or an average of 132 per year; and under the heading of "more care" during the same period, 289 deaths are shown as preventible, or an average of 96 per year. These numbers, 132 and 96 respectively, are far short of the actual numbers as many preventible fatalities included under the other headings might have been included.

It might be mentioned that the annual average number of fatalities during the three years 1896-98 was 954, of which 355 or 37 per cent. are estimated as preventible, and the foregoing conclusions, together with the writer's daily experience, lead to the inference that a number of non-fatal accidents are likewise preventible.

(8) Further Recommendations.

Having stated how some of the preventible fatalities occurred and summarized how all of them might have been prevented, amongst many others the following additional precautions suggest themselves:—

(1) *Explosions of Fire-damp and Coal-dust.*—The fireman or deputy, in making his examination before the shift commences work, should leave his chalk-mark at the innermost end of each working-place, as is done in some mines, to prove that he had examined it; and he should also mark on a paper posted in each place the time of each inspection made during the shift. In all coal-mines, the man in charge of each place should, before work is commenced and after the workmen have been out for an interval, etc., examine the place throughout with a safety-lamp, and at all times when danger from fire-damp may be anticipated, such as when clearing up falls, driving heads, etc., safety-lamps should be used.

(2) *Falls of Ground.*—(*a*) An ample supply of suitable sizes of timber should be kept as near the working-places as possible, as required by General Rule No. 22.

(*b*) There should be at the working-faces systematic timbering to suit the various seams or parts of seams, *i.e.*, a maximum distance apart (as ordered by the manager), at which such timber must be set, but it must be set as much nearer as conditions may require; suitable rules regarding this and the packing, etc., should be posted near the working-places.

(*c*) All timbering, packing, coal-getting, ripping, etc., should be done in a proper manner.

(*d*) When taking out or renewing bars, cleaning water-levels where props are set, and when widening or lowering roads sufficient catch-props should be set for safety.

(*e*) Before commencing to rid a fall, a competent person should be put in charge, who should immediately examine the place and set the necessary protective timber (bars, catch-props, etc.); in ridding away large falls difficult to make safe, care should be taken not to employ too many men thereat, and at least one competent person should have charge and constantly watch and listen for any warning that may be given by the roof or sides that further danger is near. The noise made by too many persons ridding a fall prevents such warnings from being heard.

(3) *Shafts.*—Mid-landings should be dispensed with wherever possible and no new ones made. Although the death-rate per annum through over-winding is low, and creditable to winding-enginemen and others in charge of machinery, it would be an additional safeguard to use a suspensory hook and safety-props.

There is no doubt that with heavier loads, quicker winding, and higher headgear, the conditions of danger are increased. If an overwind occurred, the hook might be perfect and act all right, but we have to deal with another danger caused by the impetus or uprush of the load, which is such that the top of the cage sometimes touches the beams. Then it falls 6 feet or more dead upon the bridle-chains, and if something gives way the cage, with its load, has to fall perhaps 30 or 40 feet until it drops on to the cage-props or goes to the bottom of the shaft. If we consider the force of impact of 5 or 6 tons falling 30 feet, we need not ask whether the props would hold it: the cage would probably break through. There is no doubt in quick winding that the use of some kind of safety-props is advisable, to meet accidents arising from the breaking of the bridle-chains or of the link which couples them.

(4) Foremen or deputies should be perfectly competent and willing to carry out conscientiously their responsible duties; and their districts should be limited, so that they are able to inspect thoroughly and attend to each place at least twice during their shift.

(5) Stallmen, hewers, colliers, or others in charge of working-places should be selected for their ability and reliability to do their duties properly and teach those under them.

(6) Officials, in all capacities, should exercise the closest observation on all things pertaining to their departments, and see that the strictest discipline is maintained.

(7) Technical education should be taken advantage of by all, to the fullest extent, to enable them the better to fulfil their duties in and about mines.

(8) Ambulance-classes should be attended by every boy and man engaged under the Coal-mines Regulation Act, in order that he may learn to render first aid so as to assuage pain, lessen danger from injuries, and save life.

(9) Trained nurses, in colliery-villages, might be the means of saving the lives of some injured persons, and would do great service in cases of serious injuries.

(10) The Workmen's Compensation Act should prove an incentive towards the employment of intelligent, well-trained officials and workmen under a good manager, who should be a strict disciplinarian.

(11) A widespread knowledge of the occurrence of all accidents

would be useful. Mr. Henry Hall, H.M. inspector of mines, in his report for 1897, stated that:—

A complete analysis of the causes of the various accidents, and such tables complete for the whole kingdom, as they will appear later on in the general mining report, should prove most valuable if widely circulated among colliery-managers and those interested. This circulation can only be ensured by the distribution of a large number of presentation copies, it is true that the published price of these reports is quite a small sum, but the majority of those who would be interested in such publications never hear of their existence, and those whom they are intended to instruct never see them. I respectfully submit that all official reports setting forth the circumstances of accidents in the different industries should be widely circulated at the public cost.* . . . . Doubtless a large percentage of the accidents are the result of want of foresight which could only have been acquired by experience, but not necessarily personal experience; the necessary warning might come from the experience of others whilst carrying out similar work. How often do we find that the same defects in machinery are repeated again and again, and that the omission of the same precautions brings about precisely similar results? If we question the overlooker where an accident has taken place, which is a mere repetition of frequent similar accidents and brought about from precisely the same cause, we often find him totally ignorant of such previous occurrences, and hence this constant and almost hopeless repetition of accidents.†

(12) Lectures on accidents might sometimes be delivered by colliery-managers to their workmen, with descriptions of accidents and the means of preventing them.

The Chairman (Mr. M. H. Mills) remarked that the paper was especially interesting to those concerned in the under-ground management of mines. It had often occurred to him that it was of very great value to read the reports of every accident that happened, and more could be learnt in that way than from anything else.

Mr. G. J. Binns remarked that the paper, when studied, would afford a large amount of valuable information.

A vote of thanks was accorded to Mr. McLaren for his interesting paper.

The further discussion was adjourned.

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* Page 11.

† Page 12.

TABLE I.—RATIO OF ANNUAL MORTALITY FROM DIFFERENT CAUSES OF ACCIDENTS IN AND ABOUT MINES CLASSED UNDER THE COAL-MINES REGULATION ACT, PER 1,000 PERSONS EMPLOYED AND PER 1,000,000 TONS OF MINERALS RAISED DURING THE PERIODS 1876-78 AND 1896-98 RESPECTIVELY.*

Years.	Death-rate from Accidents per 1,000 Persons.							Death-rate from Accidents Above-ground and Under-ground per 1,000,000 tons of Mineral raised.
	Employed Under-ground.					Employed Above-ground from All Causes Above-ground.	Employed Above-ground and Under-ground.	
	By Explosions of Fire-damp.	By Falls of Ground.	In Shafts.	Miscellaneous.	From All Causes Under-ground.			
1876	0·23	1·08	0·32	0·36	2·01	1·05	1·81	6·26
1877	0·87	1·14	0·33	0·47	2·81	0·99	2·44	8·12
1878	1·53	1·22	0·29	0·42	3·46	0·93	2·97	9·69
Averages for 3 years ending 1878	0·86	1·15	0·31	0·42	2·74	0·99	2·39	8·01
1896	0·31	0·76	0·12	0·43	1·62	0·91	1·48	4·92
1897	0·03	0·86	0·10	0·50	1·49	0·71	1·34	4·32
1898	0·05	0·76	0·11	0·45	1·37	0·92	1·28	4·22
Averages for 3 years ending 1898	0·14	0·79	0·11	0·45	1·49	0·84	1·36	4·48
Difference between the averages of 3 years ending 1878, and the averages of 3 years ending 1898...	Decrease. 0·72	Decrease. 0·36	Decrease. 0·20	Increase. 0·03	Decrease. 1·25	Decrease. 0·15	Decrease. 1·03	Decrease. 3·53
Ditto, as percentages	83	31	64	7	45	15	43	44

* *Mines and Quarries: General Report and Statistics for* 1898, *Part I.—District Statistics*, page 42.

TABLE II.—NUMBER OF DEATHS FROM DIFFERENT CAUSES OF ACCIDENTS IN AND ABOUT MINES, NUMBER OF PERSONS EMPLOYED, QUANTITY OF MINERAL RAISED, ETC., UNDER THE COAL-MINES REGULATION ACT DURING THE PERIODS 1876-78 AND 1896-98 RESPECTIVELY.

Years.	Number of Deaths from Accidents *							Number of Persons Employed.†			Mineral Raised. ‡	Mineral Raised for each Life Lost.
	From different causes Under-ground.					Total on Surface.	Gross Total.	Under-ground.	Above-ground.	Above and Under-ground.		
	Explo-sions of Fire-damp.	Falls of Ground.	In Shafts.	Miscel-laneous	Total.							
											Tons.	Tons.
1876	95	449	129	149	822	111	933	409,229	105,303	514,532	148,989,385	159,688
1877	345	448	129	187	1,109	99	1,208	395,025	99,366	494,391	148,846,260	123,217
1878	586	469	111	161	1,327	86	1,413	382,979	92,350	475,329	145,798,138	103,183
Totals for 3 years ending 1878	1,026	1,366	369	497	3,258	296	3,554	1,187,233	297,019	1,484,252	443,633,783	124,826
Averages for 3 years ending 1878	342	455	123	166	1,086	99	1,185	395,744	99,007	494,751	147,877,927	124,791
1896	173	424	68	237	902	123	1,025	557,026	135,658	692,684	208,503,868	203,418
1897	19	480	57	277	833	97	930	558,305	136,908	695,213	215,145,025	231,338
1898	27	431	64	257	779	129	908	567,124	139,770	706,894	215,161,954	236,962
Totals for 3 years ending 1898	219	1,335	189	771	2,514	349	2,863	1,682,455	412,336	2,094,791	638,810,847	223,126
Averages for 3 years ending 1898	73	445	63	257	838	116	954	560,818	137,445	698,263	212,936,949	223,203
Difference between the averages of 3 years ending 1878, and averages of 3 years ending 1898	D'crease 269	D'crease 10	D'crease 60	Increase 91	D'crease 248	Increase 17	D'crease 231	Increase 165,074	Increase 38,438	Increase 203,512	Increase 65,059,022	Increase 98,412
Ditto., as percentages ...	78	2	49	55	22	17	19	41	38	41	44	79

* *Mines and Quarries: General Report and Statistics for* 1896, *Part I.—District Statistics*, page 40 † *Ibid.*, page 36. ‡ *Ibid.*, page 37.

TABLE III.—SHOWING THE NUMBER OF FATAL ACCIDENTS AND THE NUMBER OF PREVENTIBLE FATAL ACCIDENTS IN AND ABOUT MINES UNDER THE COAL MINES REGULATION ACT FOR THE THREE YEARS ENDING 1898.

Classification of Fatal Accidents.	Mines-inspection District.													Total for Three Years.	Average per Year.
	East Scotland.	West Scotland.	Newcastle-upon-Tyne.	Durham.	Yorkshire and Lincolnshire.	Manchester. North and East Lancashire and Kent.	Manchester. Ireland.	Liverpool.	Midland.	North Staffordshire.	South Staffordshire.	South-western.	South Wales.		
EXPLOSIONS OF FIRE-DAMP OR COAL-DUST.															
Fatal accidents	11	21	5	22	70	0	3	0	1	0	6	1	79	219	73
Preventible fatal accidents ...	11	14	4	22	2	0	3	0	1	0	6	1	22	86	28⅔
Do. do. %	100	69	80	100	2	0	100	0	100	0	100	100	27	39	39
FALLS OF GROUND.															
Fatal accidents	102	98	106	134	139	92	1	145	104	50	50	92	222	1,335	445
Preventible fatal accidents ...	7	12	33	17	12	74	0	56	28	19	3	25	50	336	112
Do. do. %	7	12	31	12	8	80	0	38	26	38	6	27	22	25	25
SHAFTS.															
Fatal accidents	24	21	15	15	9	12	0	17	6	13	11	10	36	189	63
Preventible fatal accidents ..	19	12	15	13	5	11	0	13	4	12	6	5	26	141	47
Do. do. %	79	57	100	87	56	91	0	77	66	92	54	50	72	74	74

TABLE III.—*Continued.*

Classification of Fatal Accidents.	Mines-inspection District.													Total for Three Years.	Average per Year.
	East Scotland.	West Scotland.	Newcastle-upon-Tyne	Durham.	Yorkshire and Lincolnshire.	Manchester. North and East Lancashire and Kent.	Manchester. Ireland.	Liverpool.	Midland.	North Staffordshire.	South Staffordshire.	South-western.	South Wales.		
MISCELLANEOUS UNDER-GROUND ACCIDENTS.															
Fatal accidents	51	29	73	102	73	51	0	60	85	24	25	40	158	771	257
Preventible fatal accidents ...	37	21	36	31	18	26	0	30	21	10	8	21	63	322	107⅓
Do. do. %	72	72	49	30	24	51	0	50	24	41	32	52	39	41	41
TOTAL UNDER-GROUND ACCIDENTS.															
Fatal accidents	188	169	199	273	291	155	4	222	196	87	92	143	495	2,514	838
Preventible fatal accidents ...	74	59	88	83	37	111	3	99	54	41	23	52	161	885	295
Do. do. %	39	35	44	30	12	71	75	44	27	47	25	36	32	35	35
SURFACE ACCIDENTS.															
Fatal accidents	53	25	25	37	47	12	0	22	28	19	12	17	52	349	116⅓
Preventible fatal accidents ...	33	7	18	21	16	9	0	11	15	11	7	9	25	182	60⅔
Do. do. %	62	28	72	56	34	75	0	50	53	57	58	53	48	52	52
TOTAL ACCIDENTS—SURFACE AND UNDER-GROUND.															
Fatal accidents	241	194	224	310	338	167	4	244	224	106	104	160	547	2,863	954⅓
Preventible fatal accidents ...	107	66	106	104	53	120	3	110	69	52	30	61	186	1,067	355⅔
Do. do. %	44	34	47	33	15	71	75	45	30	49	28	38	34	37	37

TABLE IV.—SHOWING THE NUMBER OF FATAL ACCIDENTS WHICH MIGHT HAVE BEEN PREVENTED UNDER THE DIFFERENT HEADINGS IN AND ABOUT MINES UNDER THE COAL-MINES REGULATION ACT, DURING THE THREE YEARS ENDING 1898.

How the Fatal Accidents might have been prevented.		Mines Inspection District.														Total for Three Years.
		East Scotland.	West Scotland.	Newcastle-upon-Tyne.	Durham.	Yorkshire and Lincolnshire.	Manchester. North and East Lancashire and Kent	Manchester. Ireland.	Liverpool.	Midland.	North Staffordshire.	South Staffordshire.	South-western.	South Wales.		
EXPLOSIONS OF FIRE-DAMP OR COAL-DUST.																
(a) Carrying out the Coal-mines Regulation Act, Rules or Regulations	No.	7	9	2	20	1	0	0	0	1	0	4	0	14	58
	%	63	64	50	90	50	0	0	0	100	0	66	0	64	67
(b) Examining with or using safety-lamps where gas might be expected	No.	4	5	2	0	0	0	3	0	0	0	1	1	0	16
	%	37	36	50	0	0	0	100	0	0	0	17	100	0	18
(c) More care	No.	0	0	0	2	1	0	0	0	0	0	1	0	8	12
	%	0	0	0	10	50	0	0	0	0	0	17	0	36	15
Totals	No.	11	14	4	22	2	0	3	0	1	0	6	1	22	86

TABLE IV.—*Continued.*

How the Fatal Accidents might have been prevented.		Mines Inspection District.														Total for Three Years.
		East Scotland.	West Scotland.	Newcastle-upon-Tyne.	Durham.	Yorkshire and Lincolnshire.	Manchester. North and East Lancashire and Kent.	Manchester. Ireland.	Liverpool.	Midland.	North Staffordshire.	South Staffordshire.	South-western.	South Wales.		
FALLS OF GROUND.																
(*a*) Setting more timber, such as props, bars, chocks, etc.	No.	1	3	10	6	3	49	0	27	6	5	0	14	30		154
	%	14	25	30	35	25	66	0	48	22	27	0	56	60		46
(*b*) Setting coal or clod sprags, or by taking down clod ...	No.	2	4	8	3	0	11	0	5	8	5	0	7	17		70
	%	28	33	24	18	0	14	0	9	28	27	0	28	34		21
(*c*) More care	No.	2	2	7	2	0	9	0	8	1	6	1	1	2		41
	%	28	17	22	12	0	13	0	14	4	31	34	4	4		12
(*d*) Using a ringer-and-chain for drawing props, etc. ...	No.	1	2	4	1	3	2	0	12	11	1	1	0	0		38
	%	15	17	12	6	25	3	0	22	39	5	33	0	0		12
(*e*) Carrying out the Coal-mines Regulation Act, Rules or Regulations	No.	1	1	4	5	6	3	0	4	2	2	1	3	1		33
	%	15	8	12	29	50	4	0	7	7	10	33	12	2		9
Totals	No.	7	12	33	17	12	74	0	56	28	19	3	25	50		336

TABLE IV.—*Continued.*

How the Fatal Accidents might have been prevented.		Mines Inspection District.													Total for Three Years.
		East Scotland.	West Scotland.	Newcastle-upon-Tyne.	Durham.	Yorkshire and Lincolnshire.	Manchester. North and East Lancashire and Kent.	Manchester. Ireland.	Liverpool.	Midland.	North Staffordshire.	South Staffordshire.	South-western.	South Wales.	
SHAFTS.															
(*a*) More care	No.	3	2	7	6	3	1	0	5	0	4	1	3	5	40
	%	16	16	47	46	60	9	0	39	0	34	17	60	19	29
(*b*) Carrying out the Coal-mines Regulation Act, Rules or Regulations	No.	1	4	4	2	0	2	0	7	0	2	3	1	1	27
	%	5	34	27	15	0	18	0	53	0	16	50	20	4	20
(*c*) Adequate cage-end guards when persons are in cages ...	No.	2	1	2	3	0	0	0	0	1	3	1	1	4	18
	%	10	9	13	23	0	0	0	0	25	26	17	20	15	13
(*d*) Suspensory detaching-hooks and safety-props	No.	0	0	0	0	0	8	0	0	0	0	0	0	9	17
	%	0	0	0	0	0	73	0	0	0	0	0	0	34	12
(*e*) Shaft-belts when doing shaft-work	No.	3	2	2	1	1	0	0	0	1	2	0	0	2	14
	%	16	16	13	8	20	0	0	0	25	16	0	0	8	9
(*f*) Cage at rest at the pit-top or other landing before pushing the tub forward	No.	7	2	0	0	0	0	0	1	0	0	1	0	2	13
	%	37	16	0	0	0	0	0	8	0	0	16	0	8	9
(*g*) Not walking across the shaft-bottom or staple-bottom ...	No.	0	0	0	1	0	0	0	0	2	1	0	0	2	6
	%	0	0	0	8	0	0	0	0	50	8	0	0	8	4
(*h*) Adequate self-acting tub-controllers on shaft sidings ...	No.	0	1	0	0	1	0	0	0	0	0	0	0	1	3
	%	0	9	0	0	20	0	0	0	0	0	0	0	4	2
(*i*) Testing winding-ropes used in wet or warm shafts for torsion	No.	3	0	0	0	0	0	0	0	0	0	0	0	0	3
	%	16	0	0	0	0	0	0	0	0	0	0	0	0	2
Totals	No.	19	12	15	13	5	11	0	13	4	12	6	5	26	141

TABLE IV.—*Continued.*

How the Fatal Accidents might have been prevented.		Mines Inspection District.														Total for Three Years.
		East Scotland.	West Scotland.	Newcastle-upon-Tyne.	Durham.	Yorkshire and Lincolnshire.	Manchester. North and East Lancashire and Kent.	Manchester. Ireland.	Liverpool.	Midland.	North Staffordshire.	South Staffordshire.	South-western.	South Wales.	
MISCELLANEOUS UNDER-GROUND ACCIDENTS.																
(*a*) Carrying out the Coal-mines Regulation Act, Rules or Regulations	No.	13	11	20	19	16	17	0	13	15	6	5	8	45	188
	%	35	52	55	62	88	65	0	44	71	60	62	38	71	58
(*b*) More care	No.	19	4	11	8	1	8	0	11	6	4	3	11	17	103
	%	51	19	31	26	6	31	0	36	29	40	38	53	28	32
(*c*) Not travelling on engine-planes while endless rope sets of tubs are in motion	No.	0	2	5	2	0	1	0	6	0	0	0	0	1	17
	%	0	10	14	6	0	4	0	20	0	0	0	0	1	6
(*d*) Improved methods of shot-firing	No.	5	4	0	2	1	0	0	0	0	0	0	2	0	14
	%	14	19	0	6	6	0	0	0	0	0	0	9	0	4
Totals	No.	37	21	36	31	18	26	0	30	21	10	8	21	63	322
SURFACE ACCIDENTS.																
(*a*) More care	No.	14	3	11	10	8	5	0	3	8	7	2	4	18	93
	%	43	43	61	48	50	56	0	28	53	64	29	44	72	51
(*b*) Carrying out the Coal-mines Regulation Act, Rules or Regulations	No.	19	4	7	11	8	4	0	8	7	4	5	5	7	89
	%	57	57	39	52	50	44	0	72	47	36	71	56	28	49
Totals	No.	33	7	18	21	16	9	0	11	15	11	7	9	25	182

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, MAY 14TH, 1900.

MR. J. C. CADMAN, PRESIDENT, IN THE CHAIR.

THE LATE MR. JAMES LUCAS.

The PRESIDENT, referring to the death of Mr. James Lucas, one of the founders of the Institute, a member of the Institute till the close of his life, and at one time president, moved a vote of condolence with the family of Mr. Lucas.

Mr. W. Y. CRAIG, in seconding the motion, spoke of Mr. Lucas as a man of great ability and strict integrity, and ready at all times to oblige anyone.

The proposition was agreed to.

The minutes of the previous General Meeting were confirmed.

The following gentlemen, having been previously nominated, were elected:—

HONORARY MEMBER—
Mr. J. RICHARD HAINES, Adderley Green, Longton.
MEMBER—
Mr. HARRY SILVESTER, Newcastle-under-Lyme.

Mr. J. G. PATTERSON read the following paper on "The Howat Safety-lamp":—

THE HOWAT SAFETY-LAMP.

By J. G. PATTERSON.

(1) *The Howat Safety-lamp.*—The Howat safety-lamp is designed to burn paraffin-oil. The lamp consists (Fig. 1) of an outer shield, *A*; gauzes, *B*; a glass, *C*; a wick-tube, *J*, which extends downward from the flame-chamber, *D*, to within $\frac{1}{8}$ inch of the bottom of the oil-vessel, *K*; a ring, *E*, supports the glass and gauzes, and is permanently connected to a screwed flange, *M*, by the standards, *H*, which maintain an air-space between the oil-vessel, *K*, and the flame-chamber, *D*, with a minimum of heat-conducting area; a milled disc, *F*, for raising or lowering the wick; a small tube, *G*, which opens into the interior of the oil-vessel and to the atmosphere, and constitutes a vent for the escape of vaporized oil; and a ring, *I*, into which the oil-vessel is screwed, together with the rings, *E* and *M*, which support the glass and gauzes.

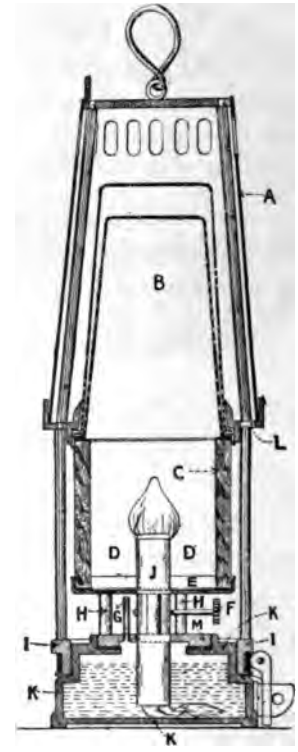

Fig. 1.

The safety of the joints at each end of the glass does not depend on the good fit of a thread. The isolation of the flame-chamber from the oil-vessel, an air-space, the circulation of air allowed in such space, and the use of a long wick-tube, enable the lamp to burn paraffin with absolute safety. The Howat safety-lamp will successfully withstand an explosive current at a velocity of 50 feet per second, when using paraffin-oil with a flashing-point of 110° Fahr. as the illuminant. The illuminating-power of this lamp, taking a standard Marsaut as unity, is 1·85.

(2) *The Patterson Gauze.*—It has frequently happened that safety-lamps have passed into the pit without gauzes. Figs. 2 and 3 show the Patterson gauzes fitted to a Howat and an ordinary Marsaut safety-lamp, and with this arrangement of gauzes it is impossible to put a lamp together except in its complete state.

Fig. 2 shows a Howat safety-lamp of the bonnetted Clanny type; *M* is a gauze fitted with a ring into which the glass fits; *N* is the case-top or middle ring, which is of so large an internal diameter that whatever sized glass is used—should an

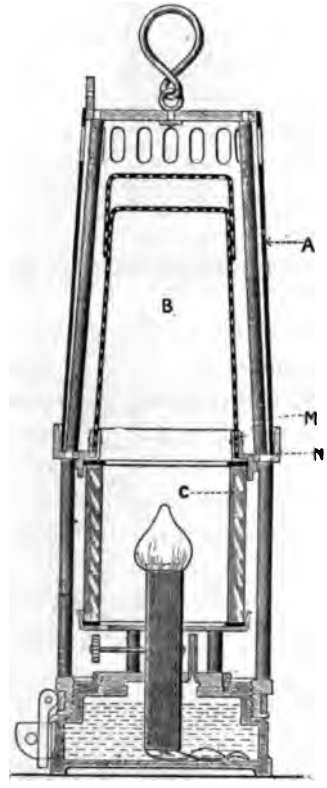

FIG. 2.

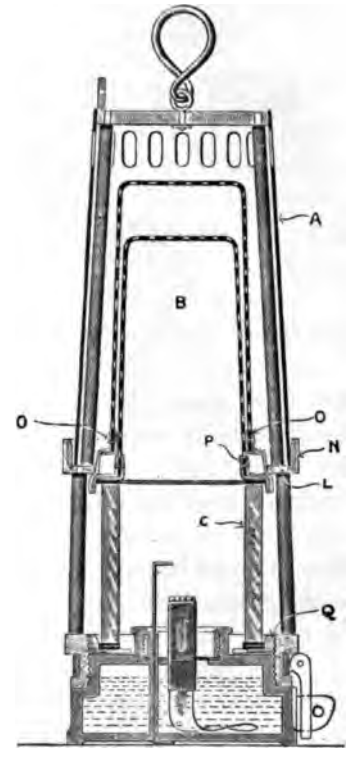

FIG. 3.

attempt be made to fit the glass-cylinder into the lamp without the gauze—the glass will pass into the bonnet or shield of the lamp, and thus show to the lampman in the most conclusive manner that something belonging to the lamp is not in its place.

Fig. 3 represents a safety-lamp fitted with two gauzes of the Marsaut type; the case-top or middle ring, *N*, is made of large diameter, the gauze-rings, *O* and *P*, are made so that, when one

gauze is inside the other and in their proper place in the lamp, they form the upper seat for the glass-cylinder; but should either or both gauzes be wanting, the glass will pass into the bonnet or shield of the lamp, and the ring or glass-holder, *Q*, will screw right through into the cage of the lamp. By this design, it is impossible for the safety-lamp to be screwed together, unless it forms a complete safety-lamp.

The Patterson arrangement does not complicate or increase the number of parts of a safety-lamp. The gauze-rings will practically last as long as the lamp; and when a gauze requires renewal, the rivets are filed off, and a new gauze is rivetted to the ring in the same holes.

(3) *The Darrah-Patterson Igniter.*—The object of this arrangement is (1) to permit of the electric ignition of safety-lamps in the mine without the risk of the connecting terminals being exposed to the atmosphere; and (2) to make more certain, when lamps have to be relighted, that the platinum wire will be brought near enough to the wick to light it.

Two terminals, *A* and A^x, are fitted on the oil-vessel, close to the thumb-screw, and a small platinum wire, *C*, is stretched between them. Each terminal is hinged and connected by a cross-bar, *E*, of slate; the support, *D*, of the terminal A^x, is placed in direct metallic connexion with the oil-vessel, but the support of the other terminal, *A*, passes through the lamp-bottom, is insulated from the oil-vessel and terminates in a stud, *G*, placed within the recess, *H*, (Fig. 5). By means of the pricker, *L*, the terminals can be pulled over the top of the wick, *B*, when lighting or relighting the lamp (Fig. 5), or pushed upward and clear of the flame, when not in use (Fig. 4).

The lighting-key (Fig. 7) for use down the pit consists of a tube, *J*, forming one terminal and screwed to fit into the recess, *H*, and an inner piece of brass, *K*, which runs through an insulated bush forming the other terminal, and to these are connected the battery wires. The tube, *J*, is free to revolve on the inner terminal, *K*, which is kept in place by a screw or pin fitting into the slot, *M*. When the lamp is to be lighted, the key is screwed into the recess, *H*, and forms one connexion through the body of the safety-lamp with the terminal, *A*; the other connexion is made by the inner terminal, *K*, coming into contact with the stud,

G, which completes the circuit, and the current makes the platinum wire, *C*, hot enough to light the wick, *B*. The breaking of the connexion between the stud, *G*, and the inner terminal, *K*, is such however that the contact is broken before the key, *J*, is completely screwed out of the lamp; and any sparking that may

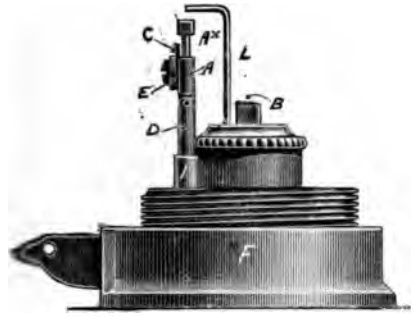

FIG. 4.

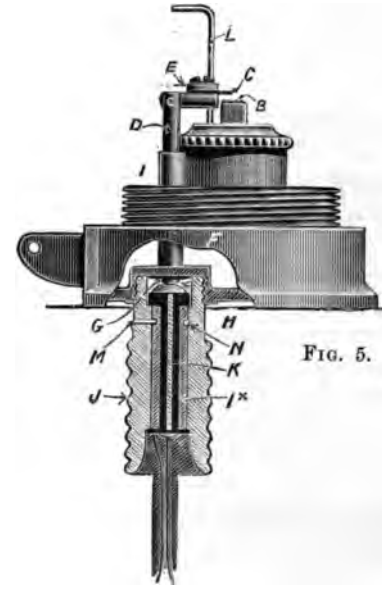

FIG. 5.

FIG. 7.

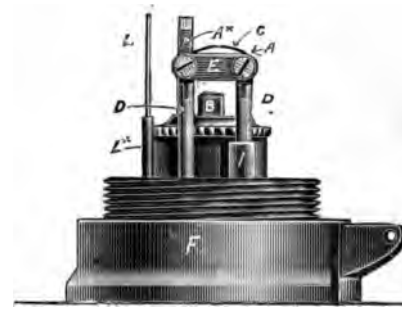

FIG. 6.

take place is effectually isolated from the atmosphere of the mine. An induced or a continuous current may be used with this arrangement to ignite the wick. For lighting the safety-lamps in the lamp-house the terminals used may be of the ordinary kind.

This lighting-arrangement does not interfere with the burner or burner-screw or with the trimming of the oil-vessel in the lamp-room.

Mr. E. B. Wain said that he felt great interest in the Howat lamp, as some years ago he tried and failed to construct a lamp-burner on similar lines, and he was pleased to see that Mr. Patterson had been able to overcome the difficulty and to shew the members a paraffin burner in which the flame was easily regulated. The space separating the flame-top from the oil-vessel was a good feature, and it afforded an easy method of regulating the flame.

Mr. John Heath said that petroleum had been burnt in safety-lamps at his colliery for six years. There was no difficulty in using it, and the flame was suitable for testing for gas. Everybody praised the lamp he used, others had adopted his lamp, but they had tampered with the principal, and spoiled the efficiency of the light.

Mr. W. N. Atkinson (H.M. Inspector of Mines) remarked that many safety-lamps burning petroleum gave a better light than lamps burning benzoline or colza-oil; and from that point of view he was in favour of the use of paraffin-oil, because he thought a good light was a necessity in a pit. If they had a good light they could get on better in many respects. This lamp was arranged to prevent danger from the rapid evaporation of the paraffin-oil. He asked whether oil would run out, if the lamp were tilted over.

Mr. Turnbull asked what was the highest temperature at which the lamp had been used in a colliery.

Mr. J. G. Patterson said that no oil would run out if the lamp were tilted over. The Howat lamp had been burnt for 4 hours in air at a temperature of 300° Fahr., with oil of a flashing-point of 110° Fahr., and there was no difference whatever in the flame, with the exception that it did not burn so brightly.

Mr. W. N. Atkinson observed that since the introduction of bonnetted safety-lamps it had been often pointed out that there was a danger of a lamp being sent into the pit without a

gauze; and in some cases that had actually taken place. The Patterson gauze-and-ring seemed to meet that danger, but the objection might arise that the arrangement introduced complications which would nullify the advantages gained.

Mr. J. R. HAINES proposed and Mr. E. B. WAIN seconded a vote of thanks to Mr. Patterson for his paper.

The motion was approved.

PRESENTATION TO MR. J. R. HAINES.

The PRESIDENT (Mr. J. C. Cadman) said that Mr. Haines and a few others were the founders of the Institute, he was the first Secretary, and save for two years he had been its Secretary till his recent resignation.

Mr. W. Y. CRAIG said that he had known Mr. Haines for nearly 30 years; and having at one time for a period of two years been president of the Institute he had an opportunity of observing how carefully the Secretary did his work. Mr. Haines had been Secretary for 25 years, and he had discharged his duties in an efficient manner. At the same time he had always been ready with suggestions to those who required them in time of need. He had not only done the Institute a service, but through the Institute he had done great service to one of the staple trades of the district. In the course of his professional duties, Mr. Haines had had a varied experience, and acquired knowledge of every conceivable phase of mining in that district, which was perhaps the most difficult to work in the world, and there was hardly any difficulty in connection with mining upon which he was not qualified to give a sound and reliable opinion. He hoped that Mr. Haines would have long life to enjoy the general esteem which he had so worthily won.

The PRESIDENT then made the presentation, consisting of a silver tray and afternoon tea-service and hot-water jug, with rose bowl, two flower-vases, and tankard. A gold ring, and a bracelet set with sapphires and diamonds, was also presented to Mrs. Haines.

Mr. J. R. HAINES, in acknowledging the gifts, said that he had

to express his fourfold thanks to the members; firstly, for the beautiful address they had given him on a previous occasion; secondly, for this handsome piece of plate; thirdly, for the kind way in which they had remembered his wife, who several years ago did much clerical work for the Institute when he was very busy; and fourthly, he thanked the members for the honour which they had done him in making him an honorary member of the Institute with which he had been so long connected. He hoped that the Institute would continue to prosper, and anything that he could do to assist his successor would always be a pleasure. He had made many friends in North Staffordshire, and sincerely trusted that the friendship would long continue to their mutual advantage. He thanked the members—one and all—not only for the beautiful and useful presents which he and his wife would always appreciate, but also for their kind expressions.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
BLAENAU FFESTINIOG, JULY 2ND, 1900.

MESSRS. GREAVES & SON'S LLECHWEDD SLATE-QUARRY.

The Llechwedd quarry was opened about fifty-six years ago by the late Mr. J. W. Greaves, and has since been worked by him and his sons. It has been worked almost entirely on the underground system, but the top from a small portion of the mine is now being uncovered, so as to make it possible to work some of the pillars that have been left. The lowest floor is situated at a depth of about 1,800 feet from the surface, and the slate-beds lie at an angle of about 30 degrees. Altogether, there are thirteen floors or galleries, each about 60 feet vertically apart. The slate is drawn from the mine by means of three inclines—two worked by steam, and one by water.

There are five large sheds, filled with 93 sawing-tables, and dressers for manufacturing slates; and four sawing-tables and three planing-tables for making slabs. In addition to the output of slates, slabs for billiard tables, tanks, etc., are produced. Over 600 workpeople are employed. Examples showed how thin the slates could be cut. One block, 5 feet long and about 9 inches wide, was split into slates less than $\frac{1}{16}$ inch thick.

All the mills are driven by water-power, by means of three water-wheels and two turbines; and a third turbine generates electricity to work three pumps, and to light the railway-sidings, etc. An air-compressor is used to supply air-power to the rock-drills. Gunpowder is used for working the slate-rock, and blasting-gelatine and gelignite for mining harder rocks.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, JULY 16TH, 1900.

MR. J. C. CADMAN, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. J. A. LONGDEN'S PAPER ON "COLLIERY CONSUMPTION."*

Mr. J. T. STOBBS said that the subject of colliery-consumption was of the highest importance, since the ratio of the colliery-consumption to the total output inversely measured the efficiency of the colliery as a whole. In many instances this ratio was, in the regular way of working, difficult to determine, owing to customs incidental to certain districts and other local circumstances. Mr. Longden stated that "the egg-ended or cylindrical (boiler) is relegated to the past,"† and speaking generally he endorsed that opinion. But at exceptional collieries, having a large number of coke-ovens, the waste-heat thus produced is more than sufficient to produce all the steam required; and under such conditions the relatively low cost of egg-ended boilers and their greater simplicity of construction (affording greater accessibility for cleaning and repairs), are advantages which will continue to weigh with those responsible for putting down such plant. In the experiments on the relative effects of hard and soft scales in a boiler,‡ it is not stated whether the chemical composition of the scales in both cases was identical; if not, there would necessarily be a difference in their thermal conductivities, which would either contribute towards or retard the general effect named—at any rate the comparison could not

* *Trans. Inst. M.E.*, vol. xvi., page 366; vol. xvii., page 253; and vol. xviii., page 145.

† *Ibid.*, vol. xvi., page 367.

‡ *Ibid.*, vol. xvi., page 367.

be instituted as being merely between hard and soft scales. Mr. Londgen also said that "the amount of water evaporated by 1 pound of nut-slack was 8½ pounds, but by 1 pound of best coal 9½ pounds of water was evaporated in a Lancashire boiler set in the ordinary way."* It was not stated whether there was any other difference between these fuels than that of size. Of course, if they were coals from different seams, or from different portions of the same seam—and it was of frequent occurrence that some parts of a seam produced more slack in holing than others—they would be of different calorific power. In modern tests of the thermal efficiency of steam-generators it is the recognized custom to determine the weight of water evaporated "from and at" the boiling-point of water under atmospheric pressure; it should therefore have been stated whether the figures given were reduced to such standard conditions. If not, it was necessary to know the temperature of the feed-water and the pressure under which the steam was raised, in order to determine the total heat of evaporation, and it was only in this way that useful comparisons could be made. Mr. Longden recommended that fine dust used as fuel should be damped so as to prevent choking of the flues; and at the same time the great deterioration in such fuel due to the absorption of moisture was pointed out—indicating a useful limit to the adoption of damping.† It would be interesting to have experiments made on this part of the subject.

Mr. E. B. Wain said that the subject of colliery-consumption was one of great importance, and at the present time, in consequence of the enhanced value of fuel, of even greater importance. Mr. Longden had given the average fuel-consumption of a number of collieries as being just over 5 per cent. of the drawings with a variation between 3 and 10 per cent. At collieries in North Staffordshire some were working at less than 5 per cent. fuel consumption whilst others were using more than double that quantity. It required only a simple calculation to prove that no expenditure on colliery-plant would give better returns from improved appliances than upon economically designed engines; and at a colliery drawing, say 500,000 tons a year, and with slack-coal at only 3s. per ton, a saving of 1 per cent. of the output would pay a return of 7½ per cent. on an outlay of £10,000 from the saving of fuel alone.

* *Trans. Inst. M.E.*, vol. xvi., page 368.

† *Ibid.*, vol. xvi., page 369.

It was not, however, necessary to incur anything like so heavy an expenditure: thus, at one colliery the application of improvements to the winding-valves so as to allow of expansive working had cost £600, and on the first year the saving was £585, reckoning the value at the pit of the fuel saved at 3s. per ton; at another colliery an outlay of £250 on improved valve-gear had effected a saving of upwards of £300 a year. With the higher current value of fuel the saving at the present time would be largely increased, and he ventured to say that even if it were necessary in some cases actually to replace large winding-engines of old type in order to obtain the necessary economy the investment would be profitable. He often found that colliery-engines were made too large for the work required, and the only method of adapting them to their actual duty was by "wire-drawing" the steam through the stop-valve. He investigated some time ago a continuous-running hauling-engine where a boiler-pressure of 80 pounds per square inch was throttled, so as to give an average effective steam-pressure of 13¼ pounds in the cylinder, which, with an evaporation of 8 pounds of water per pound of coal, gave a consumption of 7½ pounds of fuel per indicated horsepower per hour, the steam in this case being cut off at 0·90 stroke. In the same haulage engine, an initial pressure of 45 pounds, with the steam cut off at 0·20 stroke would, after making allowance for the condensation-losses, give an equivalent average effective pressure with a fuel-consumption of 3¾ pounds of fuel, or a saving due to expansive working of 48 per cent. or thereabouts.

He thought that Mr. Longden's figures were taken from the collieries whose seams lay horizontally or nearly so, and in order to compare the results with those obtained in North Staffordshire mines where the seams lie in highly inclined positions with extensive dip-workings it would be necessary not only to consider the depth of the pit but also the vertical distance through which the coal had to be raised on the haulage-road before it reached the shaft-bottom, and he knew cases where this was equal to, and even greater than the depth of the shaft. The thin seams and a small paying load (namely nett weight of coal carried) in the pit-wagons in many collieries in the North Staffordshire district would also make the comparison unfavourable as between their coal-field and the Midland district, from which Mr. Longden had taken his examples. The average load in Derbyshire collieries was rarely

under 15 cwts. of coal per tram, while in North Staffordshire a load of over 8 cwts. was the exception. Notwithstanding these advantages, he found that with a winding-engine, say 25 to 30 years old, with heavy dip-haulages, large pumps, powerful ventilating machinery such as was required in the fiery mines of the district, and detached plant which required steam-pipes to be carried considerable distances from the boilers, it had been practicable even in North Staffordshire by minor and comparatively inexpensive improvements to the valve-gears of winding and other engines to work with a fuel-consumption of less than 5 per cent. of the drawings; and he believed, with modern engines built for higher steam-pressures than were now generally used at collieries, and with suitable auto-expansion gear or tandem compound engines, that it would be practicable to work with a consumption of 3½ to 4 per cent. with mines from 1,500 to 1,800 feet deep. There was one very important point which should not pass unnoticed, and that was the question of the treatment of feed-water. Therein he agreed with Mr. Longden that the proper method of treatment was to remove as far as possible the impurities which formed the scale before passing the water into the boilers. No boiler-composition could do more than keep the scale soft, and where water contained, as colliery-water so often did, large quantities of sulphate of lime, he thought that it was not possible to use any composition in a boiler sufficiently strong to prevent the formation of scale without injuring the boiler-plates. Even if the scale were thrown down in the boiler in the form of soft mud, it was very little better from a steam-producer's point of view, than if it were a harder scale, as the mud-deposit, although more easily removed, when cleaning, could never be thoroughly removed by blowing-off and it formed a coating of non-conducting material on the boiler-shell, just as the hard scale did. Several processes were used for softening and purifying feed-waters, and he hoped before long that they might have an opportunity of hearing and discussing a paper on the question.

Mr. T. M. Favell said that much could be done in the way of economy of engine-steam. There was another thing to consider: even if they only were burning a lot of slack-coal, they were also wearing out the life of the boiler; and if they used much steam they would have a great amount of scale on the boilers, if they used bad water. It was often difficult to obtain suitable

boiler-water about collieries without treating the water chemically, and an economical system of filtration might be used to advantage. Where water was hard, he thought that the colliery-owner should soften the water by the Clarke process.

Mr. W. STATHAM asked Mr. Wain whether the saving was effected by the simple process of cutting-off at an early period of the stroke, without increasing the steam-pressure.

Mr. E. B. WAIN said that in one case the cylinders were replaced and fitted with economical valves and valve-gearing to allow the use of a higher initial steam-pressure in the cylinder and expansion working: the boiler-pressure being unaltered.

Mr. W. STATHAM remarked that in some mines they had to deal with a large volume of water, and he was not sure whether the pumping of this water was taken into consideration by Mr. Longden. Of course, if they were pumping 200 to 300 gallons of water a minute the colliery-consumption would be considerably increased. He asked whether Mr. Longden made an estimate as to the cost of raising the mineral only, or whether the cost of pumping the water was included.

The PRESIDENT said that they might use 1 per cent. at one colliery and 7 per cent. at another to pump the water, and an increase of the water would add many units to the fuel-consumption.

The discussion was adjourned.

DISCUSSION OF PROF. E. H. LIVEING'S PAPER ON "UNDER-GROUND SURVEYS," ETC.*

Mr. J. T. STOBBS said that although no word was needed in favour of the desirability of accuracy in mine-plans, yet the only means by which this accuracy could be obtained did not receive the attention that the importance of the subject demanded. Engineers knew of errors in old mine-plans, due to the use of the magnetic meridian without the necessary corrections for its variation; but many errors were due to the method (or want of method) of connecting surface and under-ground workings. The accuracy of mine-plans depended on the accuracy with which this part of the

* *Trans. Inst. M.E.*, vol. xviii., page 65.

surveying had been done, and the method described by Prof. Liveing left little to be desired in this respect; but the system was expensive and in many parts of the world the instruments would not be available, as only surveyors having a large practice would go to the expense of purchasing a transit-instrument, and it could not be expected that a colliery owner only requiring this particular piece of work to be done once or twice would purchase such an instrument. As an alternative method, and one which had given excellent results in many cases, a copper wire heavily weighted was suspended in each of two shafts, which had a direct communication at the level of the seams the workings in which were required to be connected to the surface. Then the position of the vertical plane common to the two wires was directly observed by a theodolite with relation to the lines of both surface and underground surveys; and the line joining the two wires thus formed a base-line for future surveys. If the ventilation be slackened (and this may easily be, because surveying work will be done when the shafts are free from coal-drawing); if sufficient time be allowed for the wires to come to rest (observations being made to ascertain their vibratory condition); if care be taken that the wires hang freely in the shafts, and not in contact with anything; and if readings of the angles be taken repeatedly, this method gives results comparable in accuracy with the ability to plot on paper to a scale of $\frac{1}{2500}$, and therefore while not rivalling the theoretical accuracy of the optical method described by Prof. Liveing it is (in practice) sufficiently accurate for large royalties, which it may be remarked invariably have barriers. Prof. John Perry says in a recent book "when calculating from observed quantities it is dishonest to use more figures than we are sure of," so it might be asked what was the advantage of using Prof. Liveing's elaborate method, when its theoretical accuracy was altogether masked by the errors incidental to the mechanical modes of plotting a survey to such a scale as the one named, and one which is being largely adopted for mine-plans. A less satisfactory method was to place both wires in one shaft; there was a record at the Rudolf shaft, Przibram, Bohemia, where the wires were only 7 feet apart and the survey extended 4·35 miles, comprising 210 settings of the theodolite, and the error was only 10·19 inches (0·26 metre): a result which mining engineers would admit to be most satisfactory. The increased length of the base-line in

the case of wires down two shafts should give even better results. The use of incandescent lamps, as described by Prof. Liveing, could not be so exact as the use of cross-wires; it would be interesting to know how Prof. Liveing ascertained that the carbon-filaments of both lamps were in one vertical plane. There would possibly be vibration of the filaments due to the pressure of ventilating-currents, while the effect of irregular refraction of light due to the glass globe (which could not be eliminated) was admitted by the author.

DISCUSSION OF MR. G. SPENCER'S PAPER ON "THE APPLICATION OF LIQUEFIED CARBONIC ACID GAS TO UNDER-GROUND FIRES."*

Mr. J. T. Stobbs thought that something might have been said in Mr. Spencer's paper about flesh wounds produced by liquids at low temperatures, as such wounds were very difficult to heal. It would be useful to know whether the pipes were covered or gloves used, or what was the nature of the precautions taken.

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* *Trans. Inst. M.E.*, vol. xvii., page 181.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE ROOMS OF THE ROYAL SCOTTISH SOCIETY OF ARTS, EDINBURGH,
JUNE 9TH, 1900.

MR. DAVID G. DUNN IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected by ballot:—

MEMBERS—

Mr. JAMES STIRLING, Braehead Colliery, Fauldhouse.
Mr. ALEXANDER G. STRATHERN, Gartsherrie, Coatbridge.
Mr. JAMES WEIR, Camp Colliery, Motherwell.

Mr. James McPhail was elected a Councillor in room of Mr. Robert Weir, deceased.

DISCUSSION OF MR. R. W. DRON'S PAPER ON "THE PROBABLE DURATION OF THE SCOTTISH COAL-FIELDS."*

Mr. H. M. CADELL (Bo'ness) said that the workableness of a coal-seam depended a great deal on the prices ruling. If a coal sold for £1 or more per ton, like some cannel, it would be payable if only 1 foot thick, provided the geological and other conditions were favourable. He had been in a seam of common coal only 16 inches thick, which, by means of coal-cutting machinery, and by virtue of a good roof and a soft fireclay holing under the coal, was workable at a profit even in ordinary times; and in such circumstances a coal-field could not be considered exhausted, even if there were no seams left that were over 3 feet thick. He believed that the

* *Trans. Inst. M.E.*, 1899, vol. xviii., pages 194, 331 and 393.

exhaustion of the coal-fields would be an asymptotical process. Coal-fields often lasted much longer than was expected, and he knew of one that had been pronounced by eminent mining-engineers to be almost exhausted 40 years ago; that field was producing more coal than ever. As coal became dearer, more attention would be paid to water-power as a source of energy, of which there was abundance in the Scottish Highlands, and his idea was that the pressure due to dearer fuel would be felt very gradually, and there would be time and opportunity for users of coal to accommodate themselves to the new conditions produced by a permanent rise in the price of that useful commodity.

The further discussion was adjourned.

DISCUSSION OF MR. WM. SMITH'S PAPER ON "HAULING AND PUMPING UNDER-GROUND BY AN OIL-ENGINE."*

The CHAIRMAN (Mr. D. G. Dunn) said that the oil-engine described in Mr. Smith's paper appeared to have worked with satisfactory and economical results. He rather thought, however, that for mining purposes the oil-engine had not come into that general use, which was expected upon its inception. The oil-engine, however, seemed easy of application, and provided sufficient care was exercised, was quite safe.

Mr. H. M. CADELL (Bo'ness) observed that it was an important point in favour of an oil-engine that it could be erected at a remote part of a colliery, where it might be unadvisable to use steam or electricity. The oil-engine, further, could be worked, it seemed, with great economy. They were all familiar, however, with the smells which arose from oil-engines, and of the very considerable amount of vitiated air which was produced; and in this connexion, an extra quantity of air would be required at that particular part of the workings. It would be interesting to have a comparison of the cost of oil and electrical power, because at the present time, as they knew, oil was dear, and it depended much on the economy with which the engine could be worked, whether it might be successful or not. He must say, however, that he was surprised that oil-engines were not more frequently used, and he

* *Trans. Inst. M.E.*, 1900, vol. xviii., page 396.

was rather afraid that there must be strong objections to them as practical working motors.

Mr. W. Smith replied that, at the Jellieston colliery, no difficulty was experienced from the vitiation of the return air, and five places were being worked in the return-airway. He had sometimes heard complaints when the engine was failing to ignite the charge, but no fumes were experienced if the engine was in working order. It had been stated that an allowance of 1,000 cubic feet of air per minute should be made for every unit of engine horsepower,* but in his (Mr. Smith's) experience that allowance should be doubled. It would, he thought, be more advantageous to allow 2,000 cubic feet of air per minute for every unit of horsepower.

Further discussion was adjourned.

Mr. H. M. Cadell read the following paper on a visit to "An Indian Colliery and its Miners":—

* *Trans. Inst. M.E.*, 1891, vol. iii., page 205.

AN INDIAN COLLIERY AND ITS MINERS.

By HENRY M. CADELL.

Introduction.—The coal-fields of the British Empire are not confined to the United Kingdom, and among the Queen's subjects are many thousands of miners with dark skins who wear no clothes (only one bit of cloth at most), speak no English, and live quite happily without the assistance of agitators or the excitement of periodical strikes. Year by year other coal-bearing lands are pouring their increasing output into the market, and are rearing up separate branches of the industry which in some places have entirely extinguished the demand for British fuel. The great strikes of a few years ago that disorganized business in Great Britain, and the constant agitation among our miners for higher wages and shorter hours of work, if they have not benefitted anyone in this country, have at least produced good permanent results in other parts of the Empire. A lift has been given to the collieries of India which they badly needed, and the result has been that British coal is now practically excluded from the markets of Calcutta and other great commercial centres in the East, in favour of coal produced in India, Japan and other countries where labour is cheaper than here; miners are more contented, and the voice of the professional agitator is still unheard in the land.

In December, 1899, while travelling in India, the writer had an opportunity of visiting the Karharbari colliery of the East Indian Railway Company at Giridih, in Lower Bengal, 206 miles by rail north-west from Calcutta. As this is a good example of a well-managed and successful Indian colliery, some notes on the writer's impressions may be interesting. It is not proposed to deal exhaustively with the statistical or scientific side of the matter, as that is a question of figures, plans and official reports, demanding a more intimate acquaintance with the colliery than the writer possesses. Dr. Saise has already described the geological features and method of mining in the publications of

the Indian Geological Survey* but as that memoir is not very accessible at home, some of the information which it supplies will bear repetition. The social side of the colliery and the mode of life of the miners, so unlike that of their fellow-colliers at home, interested the writer greatly and led him to put together the following notes of his visit.

Geology.—The Indian coal-measures belong to the Gondwana formation which is geologically younger than the Carboniferous system, and is from palaeontological evidence believed to be of Permian or Triassic age. These beds must once have extended over wide areas in Central India, but are now only found in patches and isolated basins which have been preserved from denuding agencies by their sheltered positions among the older rocks.

The Karharbari Coal-field.—The Karharbari coal-field is a well-defined area 11 square miles in extent, with 7 square miles of productive coal-measures. It is geologically a basin-shaped district, bounded on the north and south by parallel upthrow faults, which have brought the underlying metamorphic gneiss against the edges of the coal-bearing strata. The latter have been depressed between 600 and 700 feet in the centre of the trough, and have thus been preserved from the denudation that laid bare the gneiss at other places on the upthrow side of the faults. This is a small patch, but it is typical of many larger coal-fields in Central India.

The Indian Gondwana coal-measures appear to have been laid down in the bed of a great river, during a cold period in the geological history of that region. Scratched boulders occur abundantly in some of the beds, which point to glaciers and floating ice, and their occurrence cannot apparently be explained by any other theory of transportation.

The coal-field is situated in a country of low hills, round the sides of which the upper seams crop out, but the lower or principal seam is situated at the base of the productive measures and the present workings are mostly carried on at depths of 500 to 650 feet. The coal-seams are numerous, and sometimes of great thickness, reaching from a few inches to 20, 50 or even 90 feet in places.

* *Records of the Geological Survey of India*, 1894, vol. xxvii., pages 86-100; and *Trans. N.E. Inst.*, 1880, vol. xxx., pages 3-24.

The quality is, however, not proportional to the quantity, and the thickest seams are not necessarily the most profitable to work. The best coal contains on the average not less than 8 or 9 per cent. of ash, while this proportion rises to 20, 30 or even 50 per cent., rendering many thick seams almost worthless as sources of marketable fuel. There are several peridotite-dykes which cut up and burn the coal near them, but, subject to these drawbacks, the coal-field is very valuable, and an asset of great importance to the East Indian Railway Company.

Most of the coal is derived from the lower seam, the thickness of which is about 15 feet. The average composition of the coal is:—Fixed carbon, 66·84 per cent.; volatile matter, 24·42 per cent.; and ash, 9·15 per cent. The specific gravity is 1·35. It makes fairly good coke, and gives excellent results in locomotives as a steam-raiser.

The production is about 600,000 tons yearly, and on a liberal calculation there are still over 100,000,000 tons to work. Allowing for all deficiencies it will take over 130 years to exhaust this coal-seam, so that the Karharbari colliery has a long life before it, and the erection of good modern plant is amply warranted.

The newer shafts are sunk to depths of 500 to 650 feet, and handsome pit-head frames of steel are being erected over them. The shafts are mostly oval in section, and the massive sandstone-beds between and under which the coal-seams lie are easily cut through, so that it has been possible, under favourable conditions, to sink a large shaft at an average rate of 4 feet a day.

The coal is worked on a modification of the pillar system, and the strong sandstone-roof lends itself well to this method. The system now in vogue is to divide the area up into large blocks or districts, and drive roads outward from the shafts and main levels to the extremity of each block. The coal is then worked towards the shaft in sections, from the circumference to the centre instead of outward and in ordinary pillars, as was formerly done. The newer method prevents the robbing of pillars by the miners, and the possibility of bringing on a general creep. When pillars or sections of the coal are removed the strong roof comes away in very heavy falls, at times 400 by 150 feet in area and 30 feet high, giving rise to tremendous blasts of wind that extinguish all lights and sometimes blow out doors and stoppings. When there are indications of such falls, under-ground work has to be suspended (sometimes for a week) until all is quiet again.

There is not much gas, and naked lights are used by the miners. The native lamp is a *chiragh*, or flat earthenware lipped vessel, open at the top and 3 inches in diameter, suspended by a piece of thin wire-rope (such as a bell-wire), the strands of which are opened out, passed round the vessel and bent in under it, with a bit of cotton waste hanging for a wick over the lip.

The average temperature below-ground is about 80° Fahr., which is much cooler than that of the surface when the sun is up; so that while our coal-mines are, at most times of the year, comfortable from their warmth, the Indian miner finds his occupation more comfortable than that of the surface-labourer for exactly the opposite reason.

The Miners.—To the eye of a visitor from Great Britain, the most striking feature of the Karharbari colliery is, perhaps, constituted by the miners themselves and their way of living. The head, (and heart, too, it may be said) of this great establishment is Dr. Walter Saise, who for many years, assisted by Mr. Ward, has ably filled the responsible post of manager. Dr. Saise is, however, not merely the chief manager of a lucrative business. He is looked up to by the thousands of simple folk under his charge as a kind father and impartial judge, to whom they go for justice in their disputes and remedy in their personal grievances and family troubles.

Between 6,000 and 8,000 hands are employed at the Karharbari colliery, the numbers varying according to the season of year. An important social feature in the administration is the endeavour to let every head of a family have a piece of land, at a moderate rent, to cultivate during his spare time. This gives the owner of a croft a certain valuable social status, helps to attach him to his work, and at the same time allows him to augment his income by a healthy open-air occupation such as his ancestors lived by in the past. He owns cattle and cultivates rice, but as this work does not occupy more than three months of the year the remaining nine can be profitably spent in the mines. Although the miners work in their own time 8 hours a day, and are paid by what they produce, they are as a rule willing to assist in raising the output when the demand is specially brisk, and in this respect it would be well if our workmen at home would sometimes take a leaf out of their book. When the sum they earn as wages is mentioned a "civilized" British miner would no doubt smile con-

temptuously and think with pity of the miserable lot of these poor "black folk." But the Indian miner is in reality a great deal happier and better off with his little croft, simple requirements, and 6d. a day of wages than the British miner with twelve times the amount. His lot is the reverse of miserable, and in many cases he can save a good deal, and invest it in acquiring a larger farm and increasing his herd of live stock.

As soon as the children have passed the elementary primary examination in school, and have learned to count and to read and write their own language, which they can do at the age of from 8 to 12 years, they are allowed to begin work with their parents in the pits. As a rule, the family, after attending to their own affairs and getting a good square breakfast, go down together not later than 8 a.m. They work till 4 p.m., when they leave their places, come home, wash up, and have the rest of the evening to work on their land in the cooler hours before sunset. They descend by inclines running from the surface to depths of 500 feet, and not by shafts, and prefer this method of coming and going, as it gives them more freedom, although involving a greater amount of bodily exertion. The happy family, consisting of father, mother and say 2 or 3 children, hew and carry, or draw, on an average about 2½ tons of coal from the face in 8 hours and deliver it into tubs at the pit-bottom or up to a distance of ½ mile from the working-face.

They work in their own time and are paid for what they produce. Strikes or serious disputes very rarely take place between them and their employers. It is more likely that here, as in other parts of India, any disputes that do occur will be between people of different castes or religions. On one occasion, there was a general strike or stoppage of work, on account of an attempt by the Government to prevent women from working below-ground. This was a well-meant but mistaken piece of legislation, based on the Western ideas of some newly-appointed officials fresh from home. The result was that the hewers found, as they were deprived of their wives' assistance in getting the coal carried from the face to the tubs, that their work was brought to a standstill and no coal could be raised. The mistake was soon seen, and the women were allowed to return and work the coal according to the ordinary Oriental method.

Wages.—The family of which we have spoken, can produce on

the average 2½ tons of coal a day, for which the payment is at the rate of 4 annas (or 4d. at the present rate of exchange) per ton, amounting to a wage of 10d. for the whole family. But some miners can produce more coal than others and can earn better wages. Within the last 5 years wages have improved considerably on account of the greater demand for labour in the mines. Good miners can earn as much as 6d. or 8d. a day, and a head-sinker superintending a gang gets a rupee (or 1s. 4d.) a day, which is considered very high pay for a responsible post demanding great skill and experience. The oncostmen include sirdars or oversmen, who are paid 5d. a day. Dr. Saise, on one occasion, had constant complaints by a sirdar that the men under him were always quarrelling. He went to see what was wrong, and the sirdar called on a skilful miner who was working near by to corroborate his statement. "What," said Dr. Saise, "would you do if you were a sirdar?" "I would bump their heads together," was the prompt reply. "Then," said the autocrat of the colliery, "I promote you to be a sirdar from this moment," and a sirdar he accordingly became, and received a jacket to wear in token of the dignity of his new position. Soon afterwards, however, he came to Dr. Saise saying he did not want to be a sirdar with 5 annas a day and an honourable position of authority any longer, as he could make 8 annas by cutting coal, and besides, if he was a sirdar he must always be at his post from Monday morning till Saturday night, instead of getting a holiday every Monday and working in his own time. So he handed back his sirdar's uniform and resigned his honours for the freer and better paid, if humbler, position of a common miner.

Six years ago the average wages of miners and their wives was 1 rupee 1 anna (or about 1s. 5d.) a week or nearly 3d. a day. The daily pay for surface labour was then 2½d. for a man and 1½d. for a woman. Wages have now improved both above- and below-ground, and a surface-labourer gets 3d. or 4d. per day, while a woman can earn about 2d. or 3d. in the district. This appears ridiculous to a European, but it must be remembered that in India the climate is so hot that the natives, who spend most of their life in the open air, require no other clothes than a light cloth round their loins, and that their main article of food is rice, which they grow themselves, or buy at a very cheap rate; while their houses, which have only mud walls and a thatched or tiled roof, are almost devoid of furniture, doors or windows,

and therefore very inexpensive to build and maintain. In the famine districts, where Government was giving relief at the end of 1899 to some 4,000,000 starving peasants, the allowance was about 2 rupees a month, or, on the average, a little over a 1d. a day. It was suspected that the people found themselves so well off with this, that undue advantage was being taken of the liberality of a benevolent Government. These figures are quoted to show what ideas the Indian people entertain on the "living wage" question, if indeed they have any ideas on the subject at all, and it is with such workers that we have to compete at home. It must, of course, on the other side be remembered that Indian labour is very feeble at best, and in his own climate the British workman can, if he likes, do several times as much work as an Indian in his. But a British miner, with 12 or 14 times the pay, cannot or will not produce nearly 12 times as much coal, and consequently the total cost of raising a ton of Indian coal is just now much below what it is at home.

Working Cost.—At the Karharbari colliery, the total cost of working and raising the coal, including small sinkings, royalties, establishment-charges and salaries, is 2s. 2d. a ton, which, it need hardly be said, leaves very little room for foreign competition, even with a much better article. Large shafts of oval section, 12 by 15 feet, are sunk for about 17 rupees (or 22s. 8d.) a foot, the massive sandstone-beds above the coal lending themselves readily to the sinker's operations.

Workmen's Funds.—Dr. Saise takes much interest in the social welfare of the natives, and has established schools in their midst for the rising generation, and a benefit fund for the employees generally, applicable to all times of life, from the cradle to the grave. This fund has been in operation since 1892, and is maintained (1) by workers' subscriptions of 1d. per man and ½d. per woman per week; (2) by fines for breach of rules (1 day's to 1 week's pay, according to the gravity of the offence); (3) by wages unclaimed after a year; and (4) by interest on loans and reserve. It assists at the birth of children by a grant to defray the mother's expenses during confinement; it grants an allowance when the children grow up and are married; helps to pay the doctor's bill when they are sick; comes as a welcome visitor when they are too old to work, and require a small pension; and finally assists

at their funeral obsequies. The allowances are moderate, but so too are the requirements, and the administration is in the hands of a committee, chiefly of natives, who meet to enquire into the cases and decide as to who are fit subjects for relief. For the half-year ending June 30th, 1899:—

	Rupees.	Annas.	Pies.	£	s.	d.
The revenue was	4,438	7	9	295	18	0
The expenditure was	4,225	2	10	281	13	7
Leaving a surplus of	213	4	11	14	4	5

The details of the expenditure are as follows:—

	Rupees.	Annas.	Pies.
Allowances—Births, 376, at 2 rupees 8 annas ..	940	0	0
Do. Deaths, 61, at 4 rupees	244	0	0
Do. Do. of Children over 3 years old, 39, at 2 rupees	78	0	0
Do. Sickness, Men, 1,953, at 12 annas	1,464	12	0
Do. Do. Women, 645, at 6 annas ...	241	14	0
Do. Do. Children, 121, at 4 annas ...	30	4	0
Do. Marriages	1,000	0	0
Do. Old Age Pensions	97	8	0
Do. Gratuities to Widows	68	0	0
Refund excess recoveries of Loan	60	12	10
Total	4,225	2	10

The capital at the credit of the fund is now as follows:—

	Rupees.	Annas.	Pies.
Cash	192	8	3
Deposit on Government P. Note	11,638	0	10
Outstanding Loans	2,960	5	1
Total	14,790	14	2
Equal in British currency to	£986	1	2

There is no poor law in India, and in many cases such a fund as this supplies a real want, but cases often occur where the head of the business has to be his own law and decide how relief is to be granted.

Education.—Education, which has taken deep root in the district, up to the "3 R's" is free and compulsory. Books and slates are paid for by the pupils, and outside children, whose parents are not in the company's employment, pay fees varying from 2d. to 4d. per month. The attendance at the schools varies

from 900 to 1,000, and the number on the roll is about 1,500. The attendance is best at Christmas, when Dr. Saise provides a Christmas tree and gives a small present to each child. There are 34 schools, and it may interest educationists at home to know that the salaries of the teachers are on the average 6½ rupees (or 8s. 8d.) a month, or £5 4s. per annum and the Inspecting Pundit is paid 20 rupees a month or about £16 a year. The boys go to work at ages varying from 8 to 12 years, after they have passed the lower primary examination. Copies of the papers were given to the writer, and Dr. Saise had them translated to show the standard reached by the children at their final leaving examination. These papers show that up to the extent of the "3 R's" at least, the children are quite as clever as children at home. As the young generation becomes older, their intelligence will increase, and with an industrious contented population, and a practically unlimited field of coal the competition with the home industry is bound to grow keener every year. By and by, this fact will perhaps become apparent to these people at home, who are doing what they can to diminish the production and increase the price of British coal to the outside buyer: instead of assisting, like the Indian miners, to improve the output when the demand is brisk, and thereby to further the interests not only of their own families but of the country at large, in which they live.

Mr. R. Martin read the following paper on "An Ordinary Miner's Boring-machine adapted for Boring against Wastes":—

AN ORDINARY MINER'S BORING-MACHINE ADAPTED FOR BORING AGAINST WASTES.

By ROBERT MARTIN.

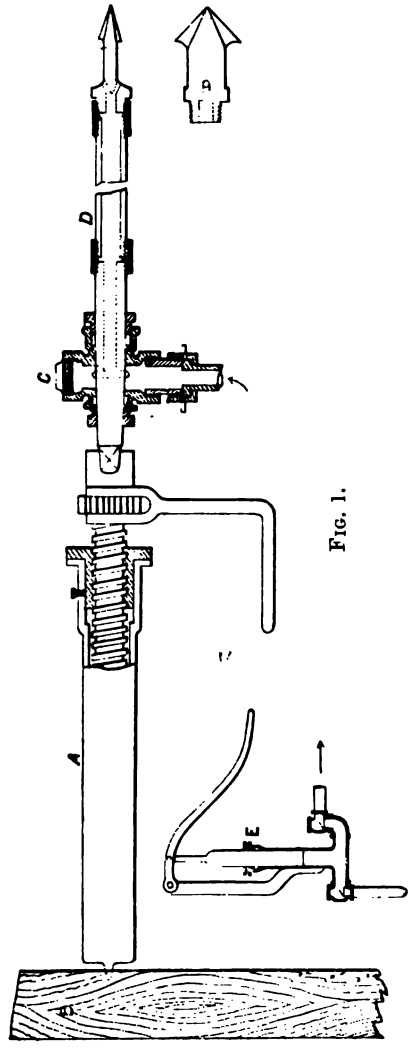


Fig. 1.

Having occasion recently, in a new colliery, to do a good deal of boring against suspected old wastes in steep ground where pressures were sure to be great, and the quantity of water enclosed unknown, the want of a suitable, easily portable boring-tool, that would bore considerable distances ahead was very much felt. None of the ordinary mining text-books describe such a machine, and those of which the writer heard were thought to be too cumberous for carrying quickly to and from steep working-faces. The difficulty with the ordinary miner's boring-machine begins when the bore-hole extends beyond the distance required for blasting purposes. The boring-tool becomes clogged, and some means is wanted to clear away the borings as fast as they are made.

What the writer wanted was a handy tool to bore front-holes and flank-holes to lengths varying from 50 to 70 feet, and the working-face never to be allowed to approach nearer the

extremities of these holes than 15 feet. This, it was thought, would always ensure an ample barrier of solid coal being left between the new and the old workings. The idea common among some miners that when straight and flank-holes are bored 15 feet ahead the coal-seam to that extent may be worked off is not a sound one, more particularly if heavy pressures are suspected.

The heaviest part of the machine to be described is the ratchet, which can easily be carried anywhere. It may be worked by one man, but the boring is more expeditiously done by a man and a boy. Fig. 1 shows an ordinary miner's boring-machine, *A*, set against a prop, *B*, in the usual fashion. The boring rods, *D*, are hydraulic tubes (1¼ inches in outside diameter and ¾ inch in inside diameter) in 6 feet lengths, which are screwed together. The cleaning of the hole is effected by injecting water by means of a small force-pump, *E*, through the hollow rods to the point of the boring-tool, which is 2½ inches in diameter. The water is passed into the tubes at a joint, *C*, through a flexible hose or the discharge-pipe from the pump. The joint was made from an asbestos-packed gun-metal cock (1 inch), suitable for the purpose. The hollow boring-rod, with a hole in it, passes through the cock in the passage made for the plug. One end of the cock is closed and the other is used for injecting the water.

With this machine, a large number of holes were bored up to 70 feet in advance by miners, with no more difficulty than there is in boring short holes. One man and a boy can bore a hole 70 feet long in a shift. No waste workings were discovered.

The CHAIRMAN (Mr. D. G. Dunn) said that Mr. Martin's paper touched upon the important subject of boring against wastes where an accumulation of water was anticipated. In the past, many accidents had arisen from errors of judgment, and it seemed very probable that this machine would obviate such accidents.

Mr. JAMES BARROWMAN observed that when approaching old wastes it was very difficult to say when they had a sufficient number of bore-holes; and it was very satisfactory to have a machine, such as Mr. Martin had described, which could be applied with so great facility.

The discussion was adjourned.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE BULL HOTEL, WAKEFIELD, MAY 25TH, 1900.

MR. W. H. CHAMBERS, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentleman was elected, having been previously nominated:—

MEMBER—
Mr. THOMAS BEACH, Mining Engineer, Hillfield, Castleford.

PROPOSED ALTERATION OF RULES.

Mr. J. R. ROBINSON WILSON gave notice that at the Annual General Meeting he would move alterations of some of the rules.

MR. GEORGE FARMER read the following paper on "Mining Accidents and their Prevention":—

MINING ACCIDENTS AND THEIR PREVENTION.

By GEORGE FARMER.

The deplorable fact that over 900 persons are killed every year in British coal-mines forcibly attracts attention to the inquiry as to what proportion of these numerous accidents are due to preventible causes, and how far a part of them are inseparable from the nature of the miner's occupation. A careful consideration of the particulars of each fatal accident, as given in the reports of H.M. inspectors of mines, leads one to the conclusion that the percentages of fatalities which might have been prevented are high, and should claim attention. When a disaster of unusual magnitude occurs, public feeling is aroused, and inquiries are set on foot; but the majority of the accidents are little noticed, except in the locality, and consequently the main difficulty in dealing with accidents rests on the necessity of maintaining a constant and unceasing watchfulness among many thousands of men, workmen as well as managers.

The total number of separate fatal accidents in all the collieries was 863 in 1899, against 828 in 1898, while the corresponding deaths amounted to 910 as against 908 in the preceding year, and 930 in 1897. Grouping the accidents under their respective causes we have:—Fatal accidents, explosions of fire-damp or coal-dust, 23; falls of ground, 424; in shafts, 67; miscellaneous accidents under-ground, 235; on the surface, 114; making a total of 863. Deaths, explosions of fire-damp or coal-dust, 54; falls of ground, 433; in shafts, 69; miscellaneous under-ground, 240; on the surface, 114; making a total of 910. Since the passing of the Coal-mines' Inspection Act in 1850, and the appointment of inspectors under the Home Office, a considerable amount of valuable information has been, and is, afforded in their published reports. By this means we are taught and kept up to date in the principles and details of practice; and many accidents are so set before us that a study of their descriptions ought year by year to

diminish their occurrence. It is sometimes said that the number of accidents or fatalities is not diminished; but if the number is not diminished, it certainly is not increased, and the results cannot but be considered as successful, for it should be borne in mind that the quantity of coal annually extracted has been, and is, largely on the increase, and a greater number of hands are employed.

Timbering.—If we review the more prolific sources of accidents, we find that the casualties due to falls of roof and sides are much more numerous than those due to any other cause, constituting something like 47 per cent. of the total deaths, and are by far the most difficult to prevent, as their occurrence is more often due to a want of care and exercise of practical experience on the part of the workmen themselves than to a want of knowledge or scientific attainments on the part of the management. The writer once heard a friend of his ask an old miner what he thought was the cause of so many falls of roof. "Well," replied the miner, "I should think it's taking th' coal out." Gruff as the answer was, there was an immense amount of truth in it; but we cannot draw the line there, we must convey to the workmen the fact that when the coal is taken out the roof and sides must be securely supported by something else—timber and packing. It is not directly to the work of such institutions as this one, that we must look for the prevention of this class of accident, but rather to the increased experience and personal care of the workmen themselves. It is, however, the work of the management of mines to see that the packing and timbering is efficiently done, and this can only be performed by employing experienced workmen, and training and teaching them on every occasion the value of efficient timbering. Mining institutions, however, can do much in this direction. The writer does not mean to say that the management should employ special timberers, and that a workman should be relieved from the burden of protecting himself, and rely entirely on the timberer. Every workman should be taught to watch the roof and to set timber to protect himself, and, as many roofs are liable to crack and fall at any time, it is essential that the workmen should be trained in this direction. The question arises as to how the workmen should be trained. An old saying is "where you cannot lead, you must drive;" it is so in this case. Some men are stupid enough

to absolutely refuse to be led, to be trained, or taught in any direction; they must be driven to do a thing by legislation before they will do it and very often try to escape that. Others, for which we must give them credit, devote every attention to the efficient security of their working-place, and take a pride in the safe and economical working of their stall.

At one large colliery in South Staffordshire, which is well-known to the writer, the manager issued regulations, entirely independent of the Special Rules in force in the district, which he caused to be printed and a copy hung at the passbye-end of every working-stall. The following is a copy:—

The distances for props to be apart on the face must not exceed 3 feet; and each prop must have a suitable lid on it. The distance between the props for a tram-road must not exceed 5 feet, and a prop must be set within 4 feet 6 inches of the buttock of coal.

The sprags under the coal must not exceed 5 feet apart, and they must be well set.

The stallmen or contractors shall see that the timber is set as above, and shall see that the workmen employed by them do not work in danger.

The stallmen or contractors shall examine the gate-end, and all parts of the stall, and if there is any danger the men must not be allowed to work.

The chain-and-bar must be used in drawing timber. Workmen found endangering their lives by neglecting to use the chain-and-bar, or by not setting timber to secure the roof and sides while drawing timber, will be sent out of the mine at once and summoned before the magistrates.

The firemen must see that the timber is set, as above, and examine the roof, coal, gate-road and wastes of each stall, and if they find any danger they shall stop the stall, and report the same at once to the underground manager. The underground manager shall go and examine the stall, and if he finds it in a dangerous state for want of the timber not being properly set, the stall must be stopped until the danger is removed, and the stallmen shall be fined not less than the sum of 2s. 6d. for each offence.

The above regulations, modified to suit the conditions of the mine, could be adopted at all mines at a very little cost, and would ensure a good systematic course of timbering, which would in no way interfere with the careful and thoughtful workman, and would enforce the sluggard to do his duty. No matter how this class of work is accomplished, it should be directly under the control and supervision of competent officials; and the working-places should be concentrated as far as possible, so as to allow of strict supervision over any district by the official in charge.

Colliery-managers and engineers can do all this, and may with advantage devote a portion of their spare time to imparting to the workmen, lectures upon mining subjects, which, if illustrated

with experiments and diagrams, may be made very instructive and attractive, and may impress upon the workmen the use of their occupation, and the why and wherefore of what they are compelled to do.

Explosions of Fire-damp and Coal-dust.—So much has been said of late concerning this source of fatality, that the writer can scarcely hope to make his remarks original and new. Although the death-rate, year by year, from this source has very materially decreased, yet it cannot be said to have given up its existence. The causes which have led to this decrease are no doubt better ventilation of the mines by the increased volume of air obtained by mechanical means, in preference to the old system of furnace; better ventilation of the working-faces, due to the more perfect knowledge of the theory and practice of ventilation; and finally the more general use of safety-lamps in all parts of the mine. The diminished use of explosives as compared with their former usage, and the almost entire prohibition of gunpowder in mines that are liable to produce gas have gone far towards the prevention of explosions; while the importance of the coal-dust theory has been so brought before us that we cannot but see its value.

Of course, every colliery-manager thinks it quite improbable that an explosion will occur at any colliery under his charge, but every colliery-manager should be prepared for the unexpected. Prevention is always better than cure, and is much cheaper than a doctor's bill. Perhaps the following suggestions may be useful:—

(*a*) Ventilation: render harmless all issues of fire-damp by a constant and adequate ventilation.

(*b*) Coal-dust: remember that coal-dust is a source of danger, inasmuch as it extends and aggravates an explosion. Many suggestions have been made, with the view of preventing coal-dust from being blown off the tubs or carried down the shaft from the surface-screens by the downcast current, or at any rate reducing the evil by means of thorough watering or mixing fine dirt with the dust. But probably the best means of avoiding the danger of coal-dust is to turn it into value, fill it up and send it to the surface: giving all the road-ways a thorough cleaning say twice or three times a year. Another method is to select portions of each main road, each such portion about 300 or 500 feet long, and, by brush-

ing or otherwise, keep these portions always scrupulously free from dust. One man would keep two or three such portions clean after the first cleaning. It is not probable that the flame of an explosion, in the absence of fire-damp, would travel over this length, without a supply of combustible material, such as coal-dust.

(*c*) Lighting: exclude all naked lights; and take proper means of ascertaining that all safety-lamps are in good working order, properly constructed, perfectly clean, and securely locked before they are taken into the mine.

(*d*) Blasting: take proper means of strictly adhering to the Explosives in Coal-mines Order.

(*e*) Competency: employ only competent men on all work involving risk and responsibility. See that only competent men are appointed to make the inspections of the mine as required by General Rule No. 4. It would be wise to appoint all men to responsible positions in writing, stating in the authority exactly what is required of them.

(*f*) Discipline: enforce rigid discipline and strict compliance with all rules and regulations.

Shaft Accidents.—Considering the number of men who daily descend and ascend our shafts, and the high speed at which we are compelled to wind; the fact that, last year, only 69 deaths were recorded, speaks very highly for the careful attention which has been given to this part of the mining machinery. Coming very conspicuously under the control of the management as this class of accident does, the skill and scientific attainments of the management should be highly valued, and, perhaps, nothing has brought this about more surely than the opportunities afforded by mining institutions. Improved machinery and improved engineering have done much. Careful supervision over the machinery, fittings of the shaft ropes, detaching-hooks, etc., can do a great deal towards the prevention of these accidents.

Miscellaneous Accidents.—This heading covers accidents from many causes, haulage-accidents, suffocation by gases from gob-fires, explosions not due to gas or coal-dust, etc. With regard to explosions not due to gas or coal-dust, but which may be occasioned from blasting-material, the number is not large, and for the most

part implies careless handling of the material. To carelessness and disregard of the rules and regulations are traceable many of the casualties reported under this heading; and probably the best prevention for them is care. Mine-discipline cannot be enforced too much, nor can carefulness be emphasized too often.

Coal-mining is a more dangerous calling than the average, but it requires only a glance at the reports of H.M. inspectors of mines to convince one that its dangers are greatly increased by the distressing lack of proper co-operation on the part of the workmen with the efforts of the employers to provide for the safety of life and limb. Probably in nine cases out of ten, the provisions made for the protection of the men while at work are sufficient for any known contingency. It is passing strange that many men seem unable to realize the importance of obeying the regulations set down for their safety. The intention of all mining laws is, of course, to render the work of the miner as safe as possible, and in order to maintain the necessary discipline every transgressor should have meted out to him "the punishment to fit the crime." Through a mistaken sympathy for the workman and his dependants, an offence may be allowed to go without other rebuke than a verbal one, or left unnoticed. This is wrong: the bars once let down, the whole fence of rules becomes valueless. Managers when besought to think of an offender's innocent family, should not fail to think of the equally innocent families of the many men whose lives were put in danger by the offence. The greatest good to the greatest number is a principle that should be applied in all such cases.

In summing up, the writer makes bold to suggest that absolutely the best preventive for colliery-accidents is technical education. There is no possible reason why every colliery-village should not have its mining classes; there is no reason why technical education should not be taken advantage of by all to the fullest extent, and this would enable workmen to better fulfil their duties in and about mines. The great aim of technical education is efficiency and safety, and efficiency and safety depend not so much on the managing director or manager as on the actual workers themselves. It is not enough to know that a certain lamp is comparatively safe, and that another lamp is not safe; every

miner ought to know why some lamps are safe and others not. It is not enough to know that certain accidents occur in mines, every miner ought to know what the causes of these accidents are. Technical education teaches this. It teaches a man the use of his labour, how to do his work safely, and how to do it in the most economical manner. It has often been said that there are already more managers than mines. What is the harm in that? The mine would be no less safe if every miner in it held a first-class certificate of competency. The writer is fully aware that many, sadly too many, miners think they know more than other men can teach them if they know how to swing a pick, or set a prop. They ignore or ridicule the manager if he invites them to a mining or ambulance class; but they heartily sing "For he's a jolly good fellow," if he invites them to drink his health. Then how are we to instil education into the minds of such men? We can do it. To educate his workmen should be a colliery-manager's aim and pleasure. He should not stop at a mining class once a week. He can reach many of his men in the mine. He can point out deficiencies, he can instruct in his orders, he can explain the why and wherefore of many things to the workmen, and, by these simple and easy means, incite such a thirst for knowledge that the workman will thank him by seeking it. The writer does not mean to suggest that lectures should be given in the mine. The mine is a place for work, and lectures are best delivered in the lecture-rooms.

The writer cannot let this opportunity pass without a word on ambulance-work, or first aid to the injured. Ambulance-work cannot be directly called a preventive of accidents, but it is certainly useful; and the classes should be attended by every man in the mine, whereby he may learn to render first aid so as to assuage pain, lessen danger from injuries, and save life. Classes should be held every year in every mining village, and the workmen and officials should be specially invited to attend by the manager of the mine. No colliery-manager should be satisfied until he had at least one competent ambulance-man in each stall. Trained nurses, in the colliery-villages, might do great service in cases of serious injuries, and might be the means of saving life.

A mining engineer has two great objects. The first is to work

his mines with the least possible loss of life or injury to the workmen employed by him. The second is to produce the minerals he is working at the least possible cost, having his first object, safety, always in view. In seeking these two objects he must, in a sense, have the co-operation of his workmen, and that is only gained by social influence, and, by means of instruction, making his workmen not mere machines but thinking human beings.

Mr. J. R. Robinson Wilson said that he had great pleasure in moving a vote of thanks to the writer of the paper. The writer seemed to think that the panacea for all accidents was technical education. He would hardly like to accept that opinion, but he had no doubt that more knowledge on the part of the workmen would result in increased safety. It was desirable that colliery-managers should be in closer touch with their workmen than they were now: colliery officials told him, however, that the men were more difficult to approach than in years gone by, and that advances made to them were not met in the spirit one would desire. The men certainly were often to blame, but he was convinced that with closer supervision many accidents might be prevented. He thought that too few bars were used in the working-places, and experience taught him that many accidents could be avoided, if more attention were given to this matter. Several collieries were adopting systematic timbering with bars across the working-face, and, so far, with excellent results. There was the question of cost; but bars should not be allowed to stand until they were shattered; they should be taken out as fast as the working-face advanced. If bars were left in the gob, the cost might be great; but the cost was not excessive if the timber was removed under adequate supervision. With increased supervision also, he thought, probably, that better pack-walls would be built along the gate-roads; many pack-walls were merely a sort of retaining wall, and they only prevented the rubbish from being shoved upon the rails. A high percentage of accidents arose from falls of roof and sides, and increased supervision would very largely tend to reduce them.

With regard to explosions of fire-damp and coal-dust, he believed that if full tubs were well moistened by a water-sprayer, as they left the pass-bye, dust would not accumulate upon the engine-plane; and, if there was a water-sprayer in the shaft, dust

could not pass from the screens down the pit. If a colliery-manager would examine the pit-bottom, he would see the fine dust from the surface settling thickly all around, and being carried for a considerable distance in-bye.

He believed that some colliery-managers in the district were holding mining classes; he knew one or two who were giving interesting lectures to their deputies, and so trying to train a better class of officials. A manager could not do better than persuade his workmen to attend mining lectures, but experience in the Barnsley district unfortunately proved that workmen would not go to be taught, even when inducements were held out to them, and facilities given them to attend.

Mr. H. St. John Durnford, in seconding the vote of thanks, said that he was inclined to think that the education of the collier would not do much good. County councils had been endeavouring for many years to induce the workmen of Yorkshire to attend lectures, but they would not attend and the money spent on the classes was mostly wasted: workmen did not want to learn, and would not learn. It was questionable whether increased safety could be obtained by increased supervision. It seemed to him that even if the deputies inspected the working-places more frequently, there would still be the probability of accidents occurring from carelessness on the part of the workmen. It was probable that increased supervision, in one form or other, would be enforced before long; and he only hoped that the results would be commensurate with the trouble and expense. The best means should be adopted to prevent flying dust from going down pits, it would be much better deposited as mud, or swept up and kept out of the pit. In some pits there was abundant muck-dust, which might not be so dangerous or harmful as coal-dust, but still it should be removed.

The President (Mr. W. H. Chambers) remarked that workmen were well aware of the amount of negligence and carelessness displayed by those working along with them, and even by themselves. He thought that the views of workmen were instructive and would, perhaps, enable the officials who were responsible for the direction of the operations of the mine, to ameliorate the bad conditions which must partly prevail in mines where so large a number of workmen were engaged with comparatively few officials to

watch over them. An official in a mine could not supervise workmen in the numerous narrow passages, roads and workings in the same way as a foreman in an engineering-works could. A deputy could not see many feet in front of him by the light of a safety-lamp. Much might be said in support of Mr. Farmer's contention that it was impossible to lessen to any appreciable degree the accidents which were happening in the mines, without the co-operation of the workmen. Since the passing of the Coal-mines Inspection Act in 1850, and its amplification and modification from time to time, very great responsibility had been thrown upon colliery-officials. He did not believe that more stringent regulations and rules would guide colliery-officials in performing their duties. A colliery-manager would not employ a deputy, unless he was assured that the candidate was well acquainted with the General and Special Rules. The mining institutes had helped to enhance the safety of mines, and no doubt, as time went on, they would add to the valuable work that they had already performed.

The motion was cordially approved.

DOCK EQUIPMENT FOR THE RAPID HANDLING OF COAL AND ORE ON THE GREAT AMERICAN LAKES.*

By ARTHUR C. JOHNSTON.

Sir William H. White, director of naval construction in the British navy, in a recent review before the Institution of Mechanical Engineers, says: "One of the most marked tendencies in recent construction has been the increase in size and carrying power of ships. Unless there had been a corresponding development in the means of dealing with cargo this increase in size could hardly have occurred, and the advantages resulting from that increase would not have been realized." And further he says: "It is well recognized that unless there is 'quick dispatch' in loading and unloading cargoes very serious diminutions of earnings must result from the longer detention in port. Hence it follows that for the complete commercial success of the larger classes of cargo carriers lifting appliances of the most efficient character and of ample capacity are of the greatest importance."† If this is true of ocean-going vessels, where voyages are, on the average, comparatively long and extended, to a much greater extent is it true of vessels carrying cargo on the Great Lakes, where, even with rapid loading and discharging of cargoes, the ratio of time spent in port to that spent in transit is very great, amounting to one-sixth under the most favourable circumstances. The object of this paper is to deal with the special types of machinery built for the purpose of insuring quick dispatch in loading and unloading the enormous tonnage of ore and coal that is shipped annually on the Great Lakes, the foundation of the gigantic steel industry that has made the United States a competitor in the markets of the world.

The shipments of ore from the Lake Superior iron-ranges represent roughly one-third of the entire freight traffic on the lakes, and

* Read before the Civil Engineers' Club of Cleveland, and published in the *Journal of the Association of Engineering Societies*, 1900, vol. xxiv., page 1.

† *The Institution of Mechanical Engineers, Proceedings*, 1899, vol. i., page 170.

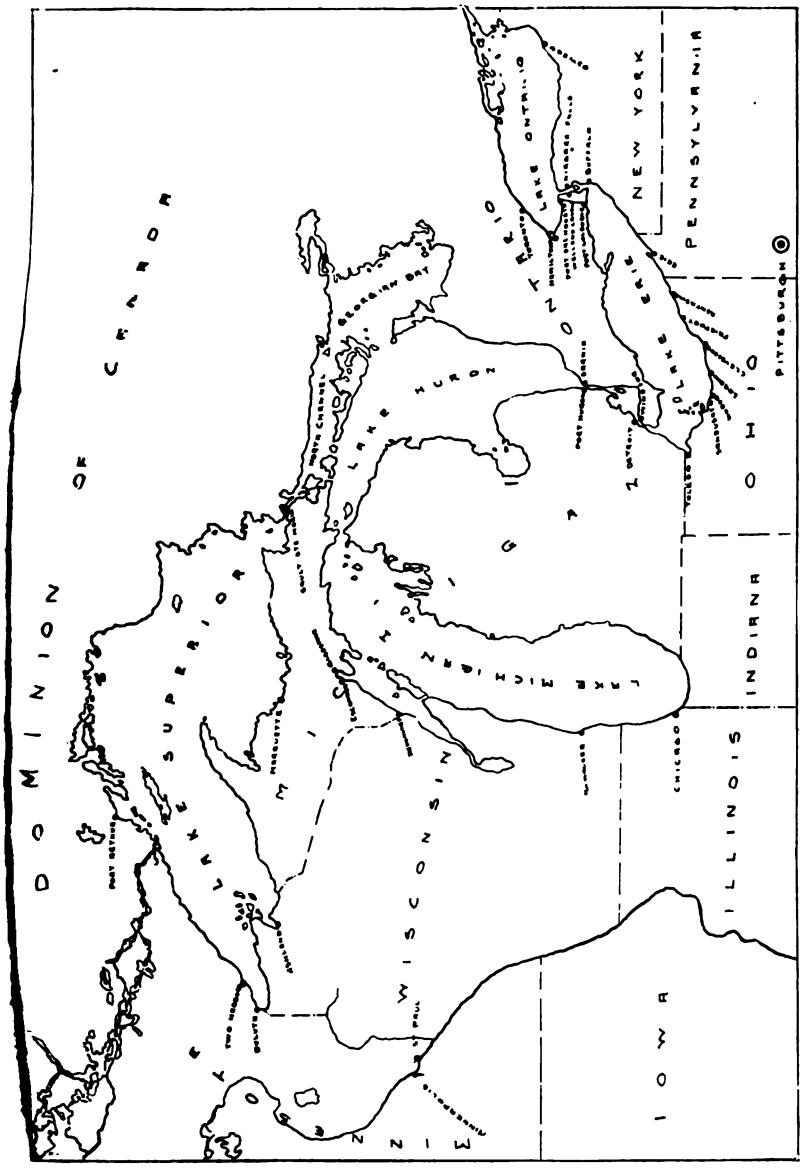


FIG. 1.—MAP OF THE GREAT LAKES, SHEWING THE PRINCIPAL PORTS. SCALE, 160 MILES TO 1 INCH.

for this reason a large fleet of modern cargo vessels has been built specially for this trade, represented as a type by the tow barge shown in Fig. 2, the steam barges being of the same general type. The largest of these are 500 feet long and 50 feet beam, the distinctive feature of these boats being the large size and number of hatches—30 to 34 feet long by 8 feet wide, spaced 24 feet centre to centre along the entire available deck length. This greatly facilitates loading and unloading operations, at the expense, however, of the strength of the deck-plating, since the ship is almost cut in two crosswise of her deck.

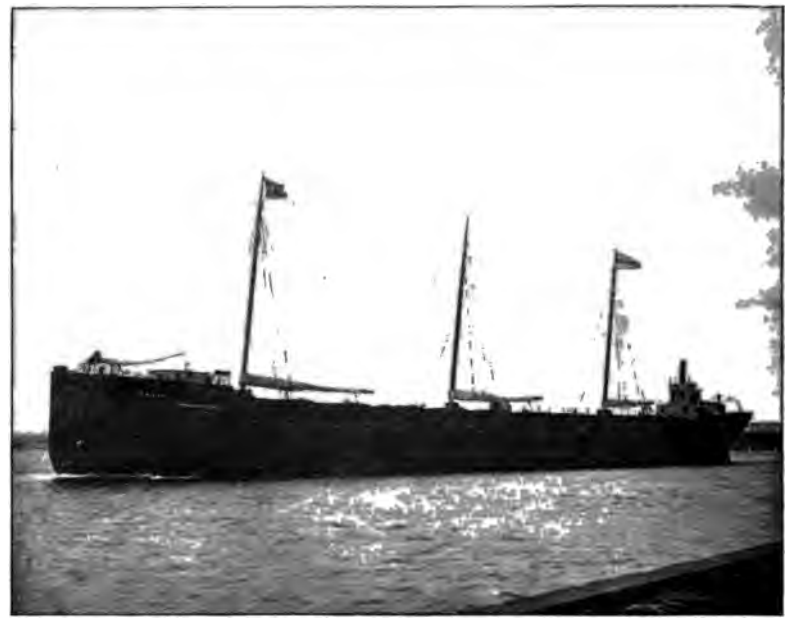


FIG. 2.—TOW BARGE "MAGNA," 3,259 GROSS TONS; 3,124 NET TONS; KEEL, 352 FEET; AND BEAM, 44 FEET.

Fig. 3 is a cross-section of a typical ore-loading dock and illustrates the method of loading vessels. The ore is dropped into the pockets from drop-bottom jumbo cars running on the tracks above, and from the pockets the chutes discharge the ore into the vessels lying alongside the dock. At the end of the season of 1898, there was, at the different points, a total of 4,354 pockets, having a total storage capacity of 623,612 gross tons of ore, constructed at a cost of about £1,400,000 ($7,000,000). The follow-

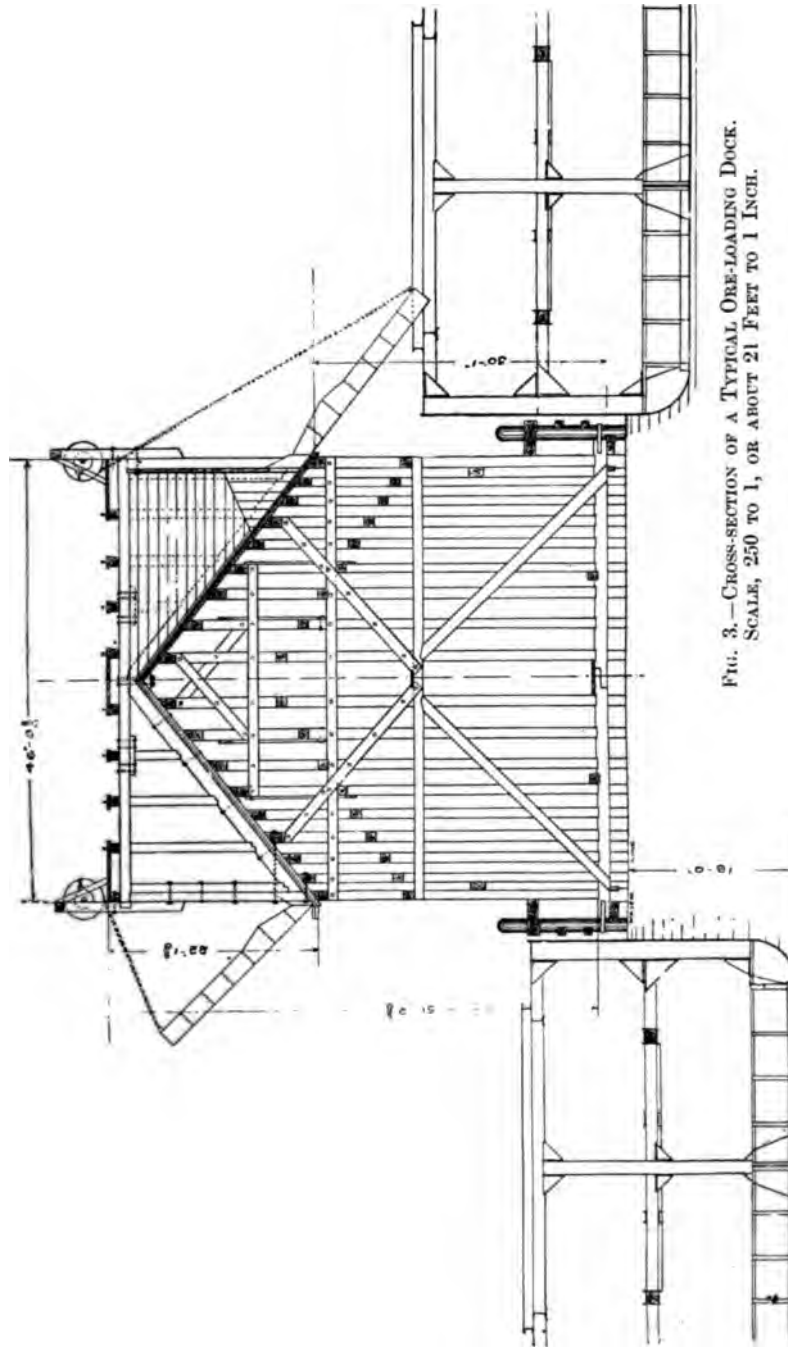


FIG. 3.—CROSS-SECTION OF A TYPICAL ORE-LOADING DOCK.
SCALE, 250 TO 1, OR ABOUT 21 FEET TO 1 INCH.

ing table gives a list of docks, with the principal dimensions and location, and the names of the railway companies owning them:

TABLE I.—LIST OF DOCKS, ETC.

RAILWAY.	LOCATION.	Dock No.	Length of Dock.	Width of Dock.		Height of Dock, Water to Deck		No. of Pockets.	Storage Capacity Gross Tons.
			Feet.	Ft.	In.	Ft.	In.		
Duluth and Iron Range Railroad Co.	Two Harbors, Minnesota.	1	1,056	41	0	45	6	141	18,000
		2	1,248	..	...	57	0	208	41,600
		3	540	49	0	51	6	90	16,000
		4	1,008	49	0	51	6	168	30,000
		5	1,008	49	0	54	0	168	33,000
Duluth, Masaba and Northern.	Duluth, Minnesota.	1	2,340	52	0	53	6	384	57,600
		2	1,738	52	0	57	4	288	42,400
Duluth, Superior and Western Railway.	Allouez Bay, Superior, Minnesota.	1*a*	300	49	8	52	0	40	12,000
		1*b*	1,200	49	8	57	0	190	25,500
Chicago and North-Western Railroad.	Ashland, Wisconsin.	1	1,404	46	8	54	0	234	36,036
		2	1,404	46	0	58	8	234	24,156
	Escanaba, Michigan.	1	1,404	37	0	46	0	184	24,104
		3	1,356	37	0	39	0	226	30,284
		4	1,500	37	0	59	2	250	37,500
		5	1,392	37	0	51	10	232	43,152
Duluth, South Shore and Atlantic Railroad.	Marquette, Michigan.	1	1,700	40	0	45	0	270	27,000
		3	1,200	53	6	37	0	213	12,780
		4	1,200	36	8	47	3	200	28,000
Lake Superior and Ishpeming.	Marquette, Michigan.	1	1,200	52	0	54	0	200	36,000
Minneapolis, St. Paul and Sault Ste. Marie Railroad.	Gladstone, Michigan.	1	768	37	0	47	0	120	15,000
Wisconsin Central Lines.	Ashland, Wisconsin.	1	1,908	36	0	54	6	314	33,500

The Duluth, Masaba and Northern Railway has now under construction a new dock which is 66 feet 6 inches in height, 62 feet in width, the heel of the spout being 40 feet above the water-line. There will be 192 pockets, with a capacity of 210 tons each. The additional width permits the placing of a track along the centre of the dock for storing empty cars and minimizing the work of the switching engines. The dock proper will require 6,500,000 feet of sawed timber and 4,780 pieces of piling.

The pockets of these docks can be filled with the different grades of ore ready to be discharged into the vessels as they arrive, and it is not an uncommon thing for a vessel to come alongside of one of these docks, take on a cargo of 5,000 tons of ore and depart within 2 or 3 hours from the time it reached port. In busy seasons, however, the vessels are loaded directly from the cars by dropping the ore through the pockets. Timbers are placed across the lower hatch to break the fall of the ore, and with proper mani-

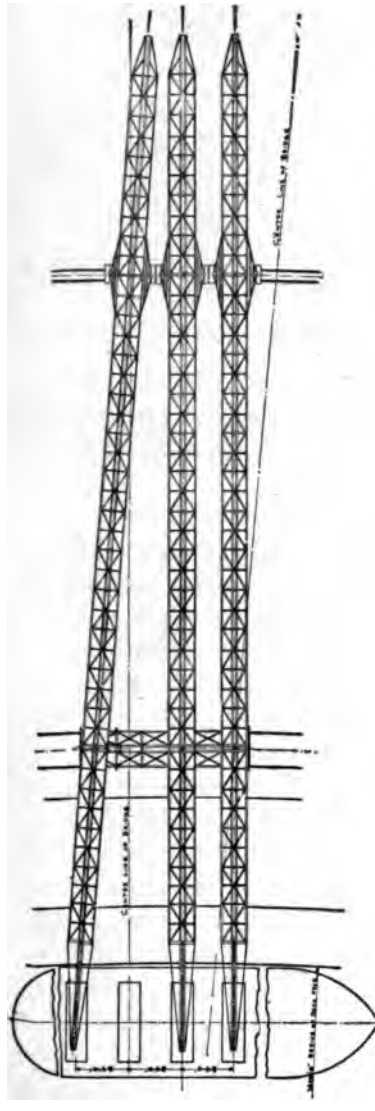


FIG. 4.—PLAN OF THE MCMYLER ORE-HOISTS AT THE DOCKS OF THE LORAIN STEEL COMPANY, LORAIN, OHIO.

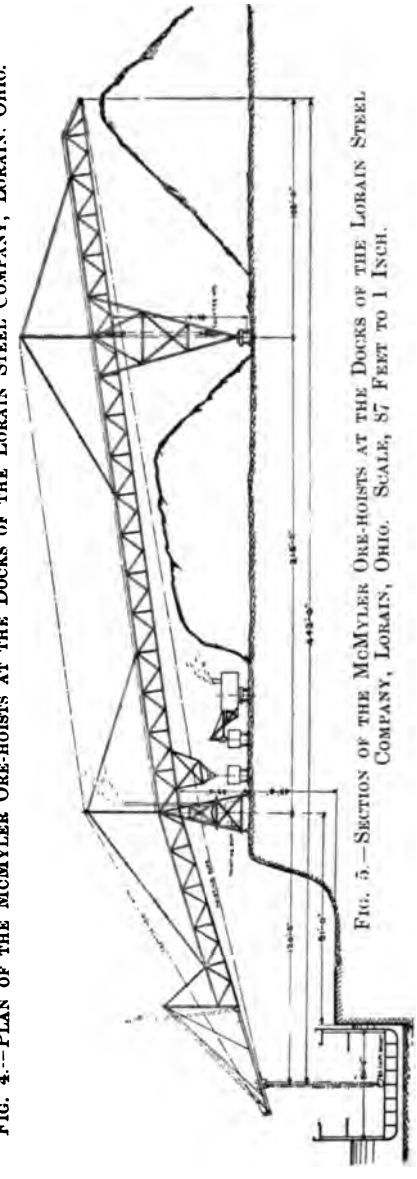


FIG. 5.—SECTION OF THE MCMYLER ORE-HOISTS AT THE DOCKS OF THE LORAIN STEEL COMPANY, LORAIN, OHIO. SCALE, 87 FEET TO 1 INCH.

pulation of the chutes, an entire cargo can be loaded with little or no trimming.

The following table gives the output of the Lake Superior ranges from 1896 to 1899, inclusive:

TABLE II.—OUTPUT OF IRON-ORE FROM ALL MINES OF THE LAKE SUPERIOR ORE REGION, 1895 TO 1899, INCLUSIVE.

PORTS	1899.	1898.	1897.	1896.	1895.
Escanaba	3,720,218	2,803,513	2,302,121	2,321,931	2,860,172
Marquette	2,733,596	2,245,965	1,945,519	1,564,813	1,079,485
Ashland	2,703,447	2,391,088	2,067,637	1,566,236	2,350,219
Two Harbors	3,973,733	2,693,246	2,651,465	1,813,992	2,118,156
Gladstone	381,457	335,955	341,014	220,887	109,211
Superior	878,942	550,403	531,825	167,245	117,884
Duluth	3,509,965	2,635,262	2,376,064	1,988,932	1,598,783
Total by lake	17,901,358	13,655,432	12,215,645	9,644,036	10,233,910
Total by rail	...	369,241	253,993	290,792	195,127
Total shipments	17,901,358	14,024,673	12,469,638	9,934,828	10,429,037

Practically all this ore is unloaded at South Chicago for consumption there, or at some of the Lake Erie ports for consumption in the Pittsburg district. The relative locations of these places will be seen on the map (Fig. 1).

One of the most recent and largest installations of ore-unloading equipments is the plant on the docks of the Lorain Steel Company, built by the McMyler Manufacturing Company, and shown in Figs. 4 and 5. The plant consists of four machines of three bridges each, the distinctive feature being the long cantilever of 127 feet overhanging the boat and the great length of bridge. On a return trip from the bottom of the boat to the extreme end of the rear cantilever the bucket travels 940 feet. As will be seen, the ore can be dumped on the stock-piles, or through the suspended hoppers into cars, which carry it to the furnaces situated directly behind the hoists. Fig. 6 shows the wagon and front stop used on these machines, and Figs. 7 and 8 show details of the 20 cubic feet bucket used. The most economical size of bucket for use in connection with ore-hoists has been found to vary from 17 to 20 cubic feet capacity, as a larger bucket is so heavy for the shovelmen to handle that much time is lost. Seventeen cubic feet contain one gross ton of light soft ore or 2,500 pounds of hard ore.

Each bridge of the conveyors shown in Figs. 4 and 5 is equipped with a pair of 12 inches by 12 inches non-reversing engines carrying a 40 inches drum directly on the crank-shaft for the main hoisting rope. As will be seen from Fig. 6, the wagon is arranged

with a three-part hoist, but in travelling along the bridge the full circumferential speed of the drum is effective on the wagon; so that a single revolution of the engine carries the wagon 10 feet 5

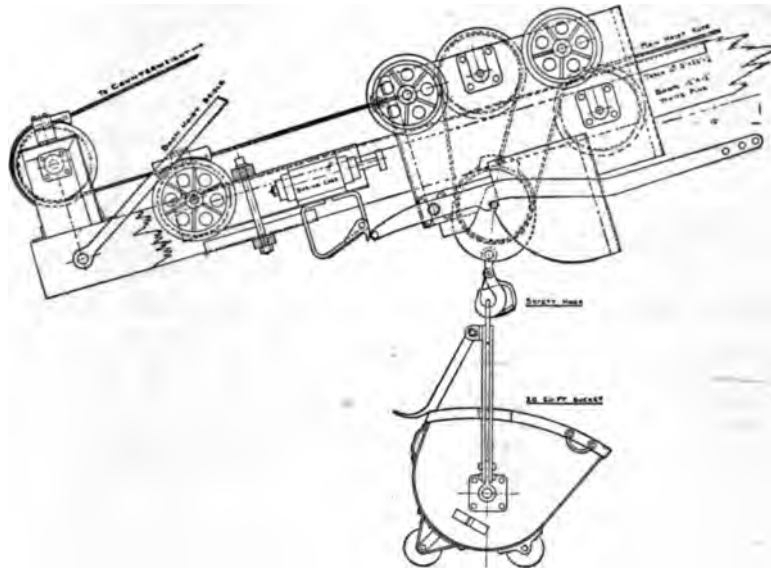


FIG. 6.—VIEW OF WAGON AND ORE-BUCKET OF THE MCMYLER ORE-HOIST. SCALE, 3¼ FEET TO 1 INCH.

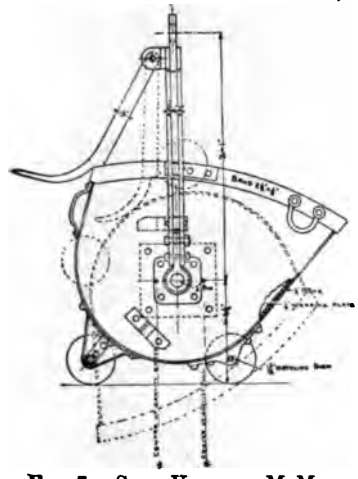


FIG. 7.—SIDE VIEW OF MCMYLER 20 CUBIC FEET ORE-BUCKET. SCALE, 29 TO 1.

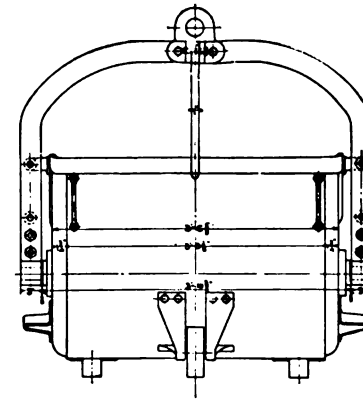


FIG. 8.—END VIEW OF MCMYLER 20 CUBIC FEET ORE-BUCKET. SCALE, 29 TO 1.

inches along the bridge in trolleying, or lifts the bucket 3 feet 5⅝ inches in hoisting, thus making the machines very quick in action. In returning the wagon, the incline of the bridge is aided

by a counterweight in the rear tower. The main hoisting ropes are $\frac{5}{8}$ inch in diameter ($\frac{1}{2}$ inch ropes having been found too light for the severe service), running on 24 inches sheaves, except in the wagon, where they are 17 inches, and in the hanging block, where they are $14\frac{1}{2}$ inches in diameter. The engines have auxiliary drums for hoisting the boom or apron that overhangs the boat, and they are also arranged to move the front end of the bridges in or out from the centre bridge in order to accommodate any spacing of hatches and to propel the front tower along the track parallel to the dock-face. The rear towers are moved by a locomotive on a parallel track. The returning wagon is controlled by a band-brake on the drum, worked by the foot of the operator. These machines have made some remarkable records in point of speed, as an individual wagon has made 50 return trips per hour, carrying the bucket from the bottom of the boat to a point halfway between the towers. The best cargo record was 3,241 gross tons taken out in $12\frac{1}{2}$ hours by 6 bridges. The operator is located in the front tower in these machines, in full view of the hatch, which makes the matter of getting the bucket up and down through the hatch much easier and quicker than when he is further removed from the boat.

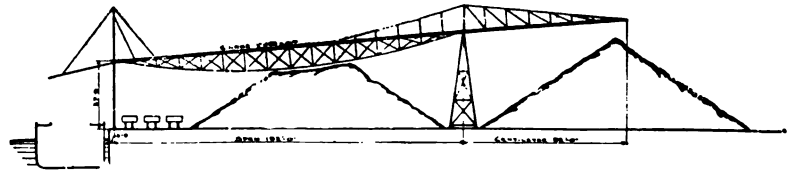


FIG. 9.—BROWN ORE-HOIST. SCALE, 107 FEET TO 1 INCH.

Fig. 9 shows the type of unloader built by the Brown Hoisting and Conveying Machine Company, the pioneers in the building of dock machinery on the lakes. It differs from the McMyler hoists, already described, in the type of towers employed and in the arrangement of the towers. The engines also have a single reduction gearing between the crank-shaft and drum, thus using a smaller engine with higher piston speed. The machines are generally arranged in groups of two, with the engines and boilers and operators in the rear tower. Both towers are generally moved along the dock by hand. There are over 175 bridges of the Brown type of conveyor at the different Lake Erie ports.

Fig. 10 shows another type of ore unloader built by the King

Bridge Company. Its distinctive feature is the great freedom of motion of the bucket. In both the Brown and McMyler types, the hanging block is locked in the wagon, and cannot be released without striking a stop which is bolted between the tracks. Thus, when unloading very narrow boats, the front stop on the apron must

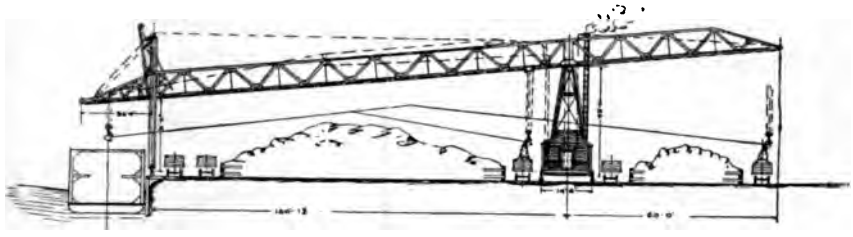


FIG. 10.—KING ORE-HOIST. SCALE, 83 FEET TO 1 INCH.

be moved in till it is vertically over the centre of the hatch, and, similarly, for loading into a car on a track under the rear cantilever a stop must be placed over the centre of the track to allow the bucket to be lowered in order to reduce the drop of the ore. In the King machine, however, the bucket can be raised or

FIG. 11.—MCMYLER DIRECT-ORE-UNLOADERS AT THE DOCKS OF THE PITTSBURG AND CONNEAUT DOCK COMPANY, CONNEAUT, OHIO.

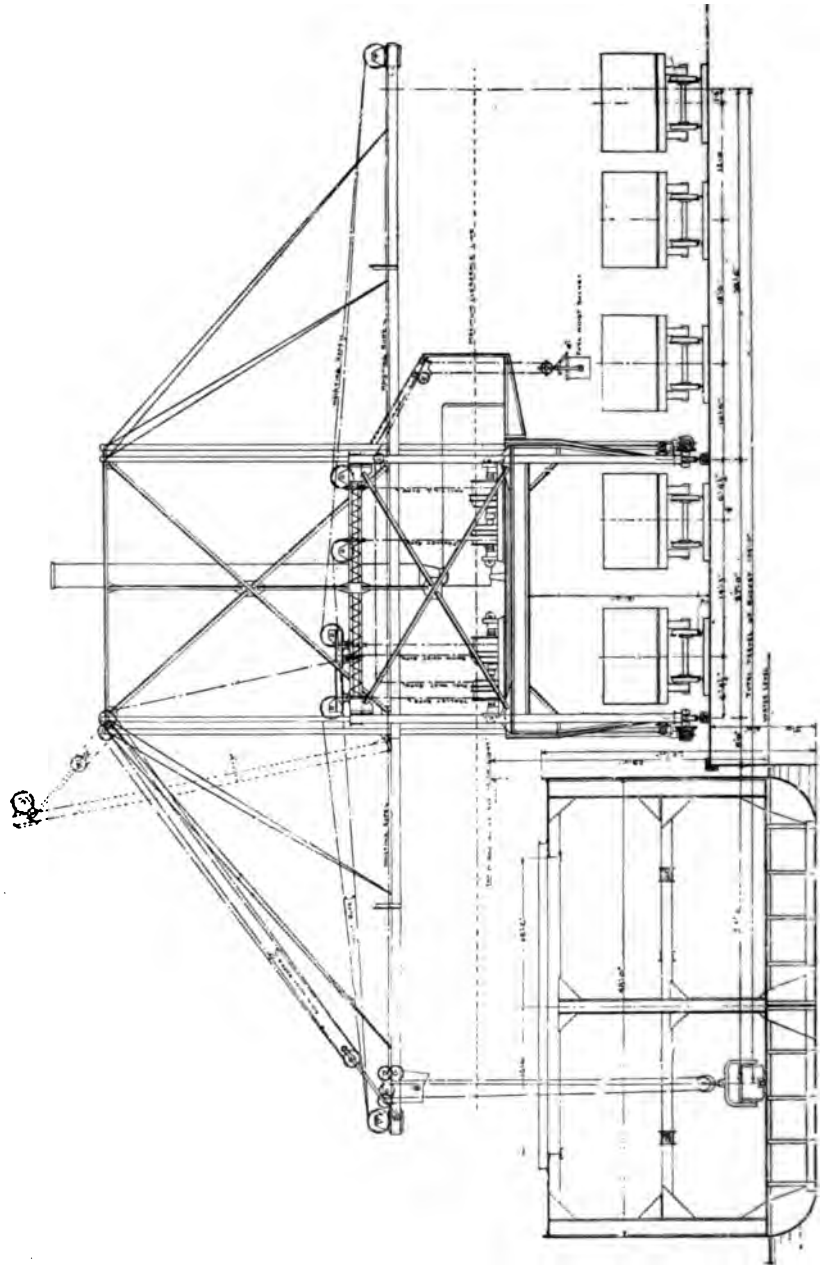


FIG. 12.—SECTION OF McMYLER DIRECT ORE UNLOADER AT DOCKS OF THE PITTSBURG AND CONNEAUT DOCK COMPANY, CONNEAUT, OHIO. SCALE, 250 TO 1, OR ABOUT 21 FEET TO 1 INCH.

hoisting, run on 24 inches sheaves, except in the wagon, where they are 17 inches, and in the hanging block 15 inches in diameter. It is made impossible for a rope to leave the sheave by the use of the very simple guard shown in Figs. 13 and 14. The machines can travel along the dock by steam, and the racking of bridges is also effected by the engine. All movements other than hoisting and trolleying of the bucket are accomplished by means of a jack-shaft driven by a pinion on the crank-shaft of the main engine. Under actual working conditions the capacity of the plant of 12 bridges at Conneaut is 6,000 gross tons per day.

In a similar direct unloading plant built by the Brown Hoisting and Conveying Machine Company on the C. and P. docks at Cleveland the drum is geared to the crank-shaft, and the suspended hook is used. In neither the Brown nor the McMyler direct unloaders is the hanging block locked in the wagon, except to obtain the maximum clearance under the bucket. The lock on the wagon is very handy, however, to hang empty buckets from when the machine is idle.

With all these machines, in which the buckets are filled by hand, the actual cost of handling the buckets is very small, varying according to how nearly up to its full capacity a machine is worked; but under actual working conditions, from figures prepared by Mr. A. E. Brown, the cost per gross ton of ore handled by his machines varies from 0·35d. to 0·68d. (0·70 cent to 1·37 cents). But the greater expense is incurred in filling the buckets. The shovelmen are paid from 5¼d. to 6½d. (10½ cents to 13 cents) per gross ton, so that, at an average rate of 5½d. (11 cents) per ton, it cost £400,000 ($1,980,000) for shovelling to unload the 18,000,000 tons of ore shipped this year. It was to reduce this cost that the Hulett ore unloader, shown in Figs. 15, 16 and 17, was designed and built by the Webster, Camp & Lane Machine Company for the Pittsburg and Conneaut Dock Company at Conneaut. Up to the present not enough has been done with this machine to obtain any data in regard to its performance. Its method of operation will be evident, however. The bucket is designed to lift 10 tons of ore at one scoop and dump it into the railway cars, or into a skip which can deliver it to the stock piles. All the motions on the trolley carrying the tilting girder are effected by hydraulic power, the pumps and tank being carried on the trolley itself, and the steam-loaded accumulator is used to partly balance the weight of the bucket. The operator is located

FIG. 15.—HULETT ORE-UNLOADER AT DOCKS OF THE PITTSBURG AND CONNEAUT DOCK COMPANY, CONNEAUT, OHIO.

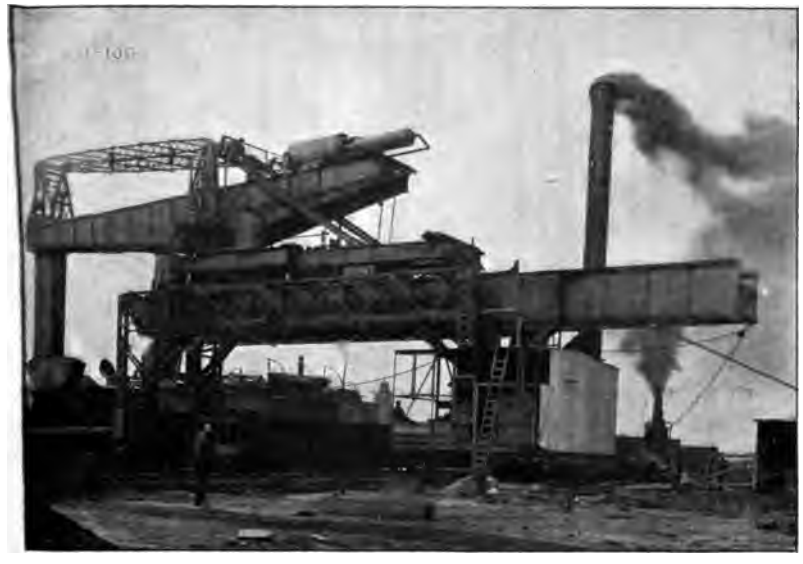


FIG. 16.—HULETT ORE-UNLOADER AT DOCKS OF THE PITTSBURG AND CONNEAUT DOCK COMPANY, CONNEAUT, OHIO.

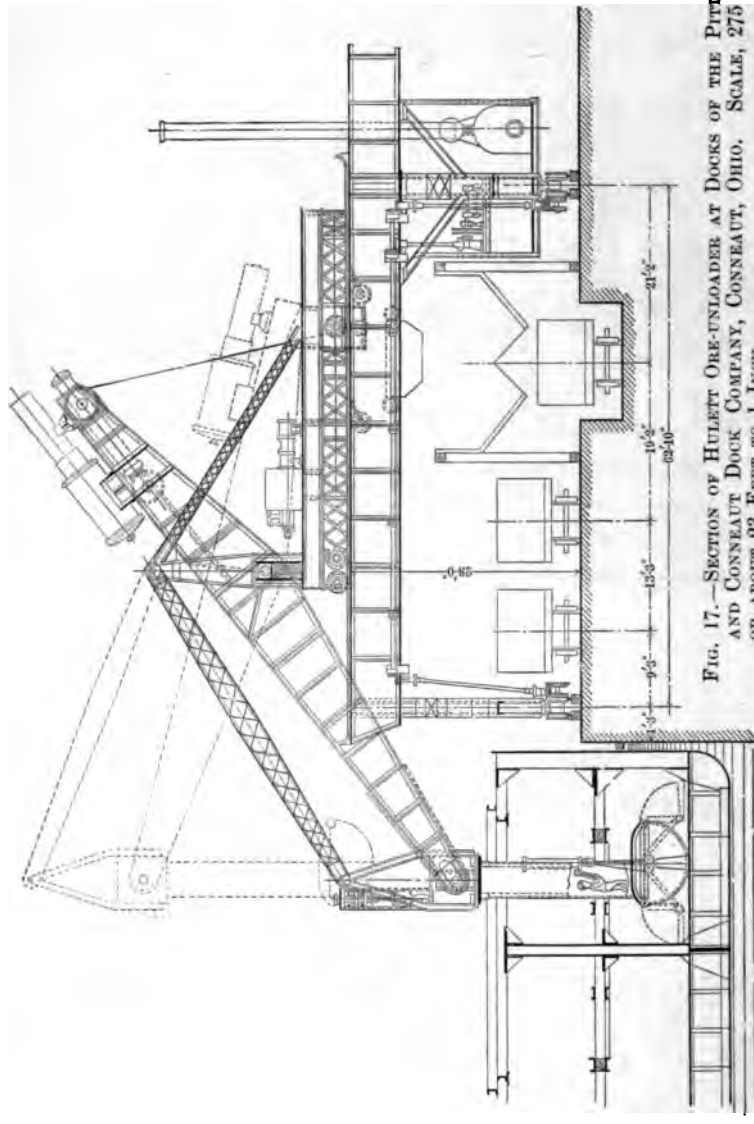


FIG. 17.—SECTION OF HULETT ORE-UNLOADER AT DOCKS OF THE PITTSBURG AND CONNEAUT DOCK COMPANY, CONNEAUT, OHIO. SCALE, 275 TO 1, OR ABOUT 23 FEET TO 1 INCH.

just above the bucket, and descends into the hatch with it. The bucket can rotate in either direction about the axis of the vertical ram, thus enabling the ore lying in between hatches to be reached. It is expected that very little of the ore will have to be shovelled by hand with this machine.

The large vessels returning from the lower lake ports go up in water ballast or take a return cargo of coal; and to facilitate the

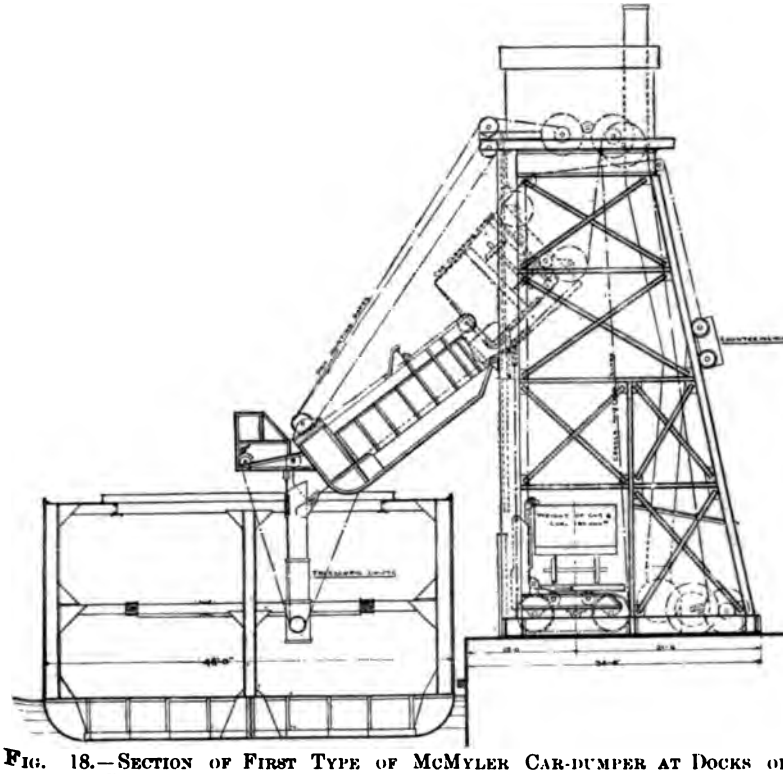


FIG. 18.—SECTION OF FIRST TYPE OF MCMYLER CAR-DUMPER AT DOCKS OF THE CLEVELAND TERMINAL AND VALLEY RAILWAY, CLEVELAND, OHIO. SCALE, 275 TO 1, OR ABOUT 23 FEET TO 1 INCH.

loading of the enormous tonnage that is carried to the upper lake ports each year the car-dumper has been developed,—a machine which picks up bodily a car weighing 17½ tons and carrying 40 tons of coal and empties the contents into the hold of a vessel at the rate of as high as 30 cars per hour. Fig. 18 shows the first type of McMyler side-dump machine built on the lakes. The first successful machines were of the end-dump type, but they require special cars. They are still in operation, one at Ashtabula and one at Fairport. The machine shown in Fig. 18 is very flexible

in operation, as the hinge of the apron may be raised or lowered vertically to suit any class of vessel, and the car and cradle in ascending begin to turn over on striking the hinge point of the apron. This machine has been built with several types of chutes, but perhaps the most successful is the telescopic chute shown, as by its use much trimming of cargo is avoided. The car-clamping mechanism is beautifully simple, being merely four chains with counterweights suspended, the chains wrapping round the car as it is overturned. The cable is hoisted by four 1¼ inches cables arranged as a two-part hoist on 45 inches drums, driven through double reduction gearing by a pair of 14 inches by 18 inches engines. The load is lowered by using the engines as air-pumps and throttling the exhaust, or with a foot-brake, as desired. In operation the machine, though so powerful, is extremely simple, considering the work it accomplishes, and has a record of thirty-two cars an hour; but of course this speed cannot be maintained, on account of delays in switching cars and shifting the boat to reach different hatches. There are three machines of this type in operation; one on the docks of the Cuddy-Mullen Coal Company at Cleveland, one on the docks of the Cleveland Terminal and Valley Railway at Cleveland and one at Erie, Pennsylvania, on the docks of the Erie and Pittsburg Railway.

Fig. 19 shows the latest type of McMyler car-dumper; designed to handle the coal more gently, in order to reduce the breakage to as small a percentage as possible. There are also three of these machines in operation; one operated by the Pittsburg and Conneaut Dock Company at Conneaut, Ohio, another by the Cleveland, Lorain and Wheeling Railway at Lorain and a third at Ashtabula. As will be seen, the coal is first dumped into a pan, which is partly overturned to receive the coal as it rolls out of the car. The pan is then hoisted—the car being lowered meanwhile —until the chute is reached, when a door in the pan opens automatically and discharges the coal into the chute. This machine is also very fast, and handles regularly, under working conditions, 1,000 tons of coal per hour. All the motions, with the exception of hauling the cars onto the cradle, are performed by a single pair of 16 inches by 18 inches engines. The car and cradle are hoisted by eight 1⅛ inches cables on 60 inches drums, geared to the crank-shaft by single reduction gearing. The operations of hoisting and tipping the pan are accomplished with sixteen 1 inch ropes on four drums 40 inches in diameter.

The Brown Hoisting and Conveying Machine Company has built five car-dumpers that handle the coal still more gently, but on that account they are necessarily slower in operation. With these machines the coal is dumped from the cars into six buckets

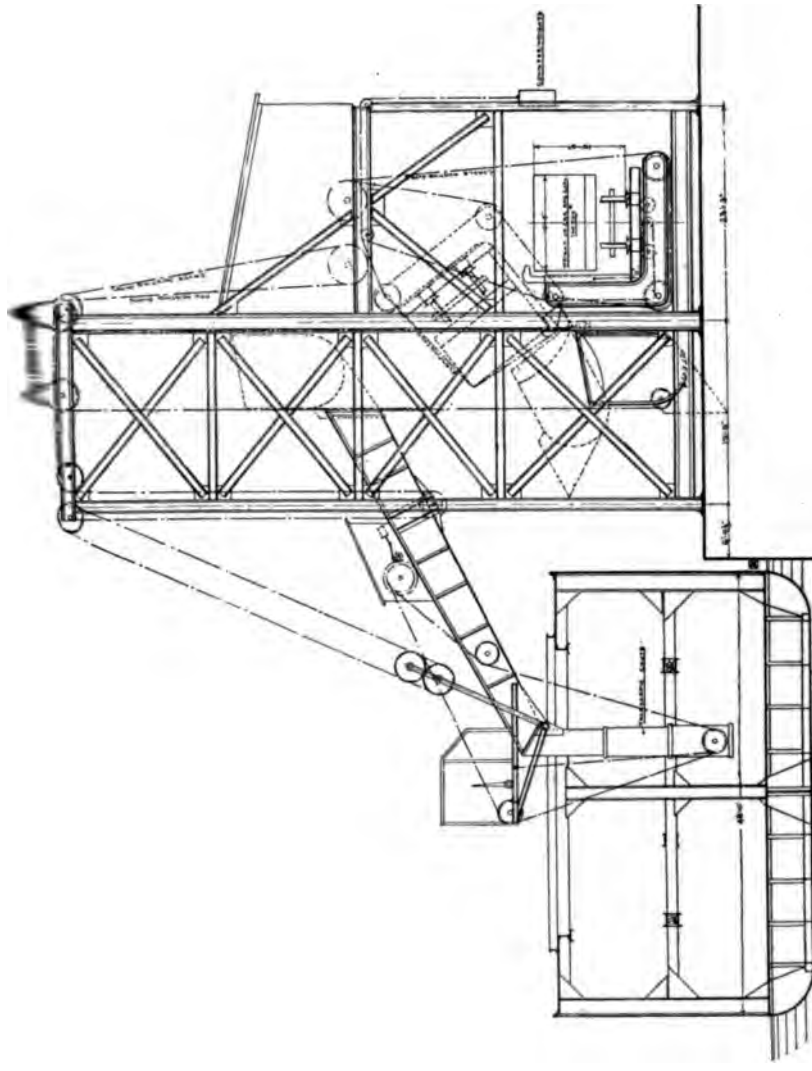


FIG. 19.—SECTION OF LATEST TYPE OF McMYLER CAR-DUMPER AT DOCKS OF THE PITTSBURG AND CONNEAUT DOCK COMPANY, CONNEAUT, OHIO. SCALE, 275 TO 1, OR ABOUT 23 FEET TO 1 INCH.

carried on a transfer car. Each of these buckets is then lifted by either of two travelling cranes, which carries it out over the boat and lowers it into the hatch when the bottom is opened and the bucket drawn away, thus placing the coal very gently and just

where wanted. The mechanical arrangements are very ingenious and well executed in securing the complicated motions necessary.

The Hulett car-dumper, built by the Webster, Camp & Lane Machine Company for the Rochester and Pittsburg Coal and Iron Company at Buffalo, works somewhat on the principle of the Brown car-dumper, but it is much simplified by using only two buckets; in fact, the whole machine is comparatively simple. The clamping mechanism is of the same type as that of the McMyler machine. The engines for tipping the cradle are located underneath same, while those for controlling the buckets are located on the platform on top of the machine. The tracks on which the trolleys carrying the buckets run can both be swivelled about a pivotal point by hand to suit any spacing of hatches. The machine can handle regularly twenty cars an hour, but the switching room at Buffalo is so limited that a sufficient supply of cars cannot readily be made accessible to the machine.

A novel design of car-dumper is shown in Figs. 20 and 21, built by the Excelsior Iron Works Company for the Erie Coal Transfer Company at Cleveland. This is an exceedingly fast machine, and its operation is very simple. The loaded car is pushed into the cylinder by a locomotive, and the cylinder and car are turned over by a steam cylinder of long stroke operating through a two-part rope. In turning over, the car is supported on its side by a hydraulic cylinder and clamped on top by a simple device. The machine is well adapted to its peculiar location, where the bank of the river is very high, but the fall of the coal is considerable.

In all car-dumpers, the speed depends largely on the switching arrangements and on the storage capacity for loaded and empty cars. The three methods in use for bringing the loaded cars into the machine are: (1) by means of a locomotive; (2) by storing the loaded cars on tracks having a down grade into the machine; and (3) by the use of a haulage mule similar to that shown on Fig. 23. In the last case there is a grade up into the machine. The loaded car pushes the empty car out in all cases.

Car-dumpers are also used for fueling vessels, although some of the fuel hatches cannot be reached by the chutes; but most docks handling fuel alone are equipped with coal-pockets at a sufficient elevation to discharge the coal through chutes into the coal-bunkers, the pockets themselves being filled by drop-bottom

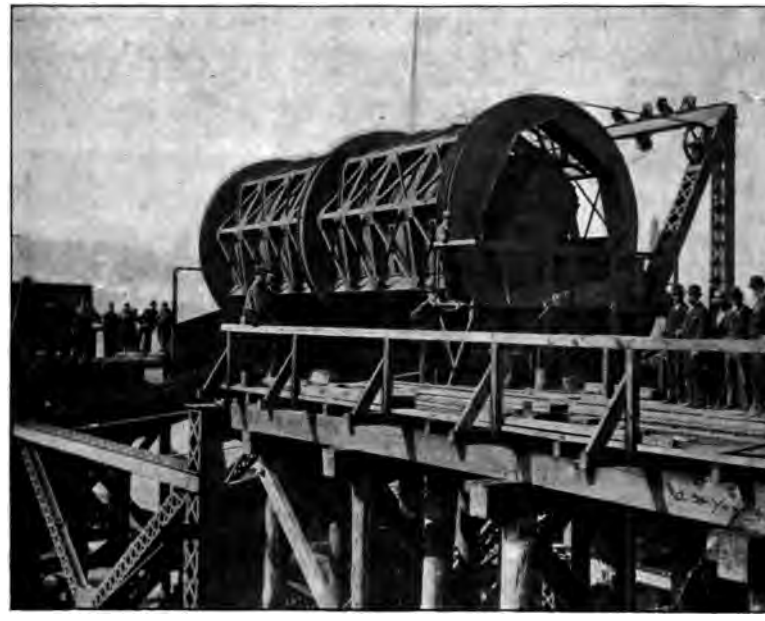


FIG. 20.—VIEW OF CAR-DUMPER AT DOCKS OF THE ERIE COAL TRANSFER COMPANY, CLEVELAND, OHIO.

FIG. 21.—VIEW OF CAR-DUMPER AT DOCKS OF THE ERIE COAL TRANSFER COMPANY, CLEVELAND, OHIO.

cars from a track carried on top. Figs. 22 to 25 show the equipment of a large fueling dock operated by the Cuddy-Mullen Coal

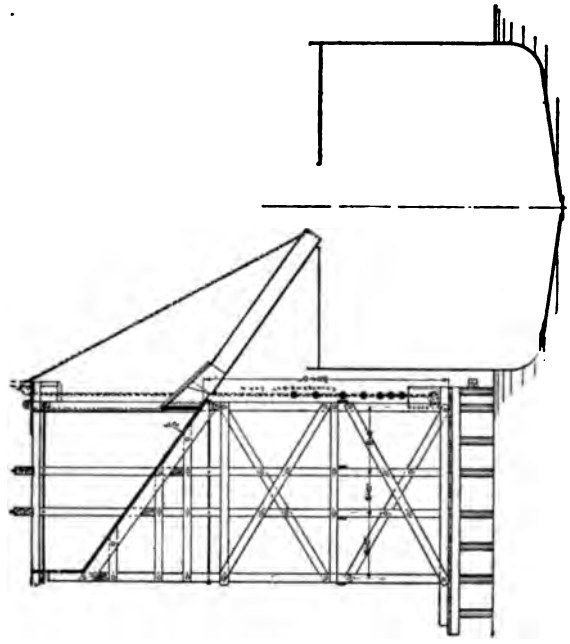


FIG. 22.—SECTION THROUGH COAL-POCKET.

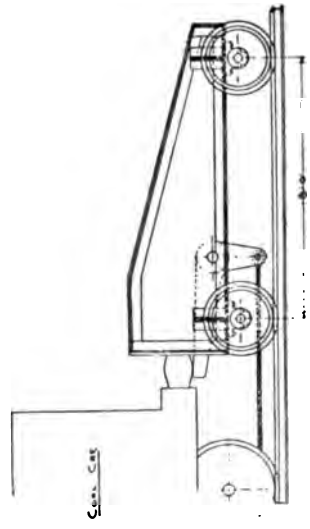


FIG. 23.—SIDE VIEW OF HAULAGE-MULE.

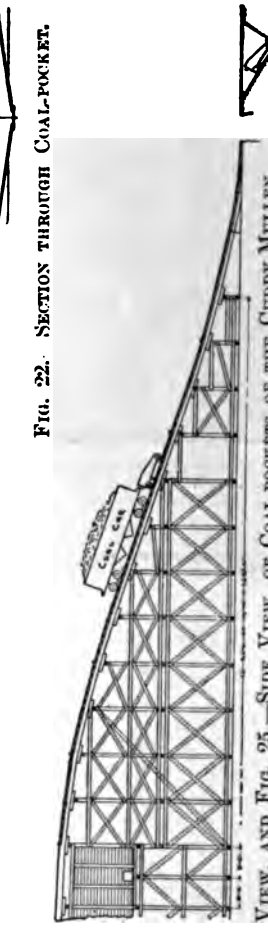


FIG. 25.—SIDE VIEW, OF COAL-POCKETS OF THE CUDDY-MULLEN COAL COMPANY, CLEVELAND, OHIO.

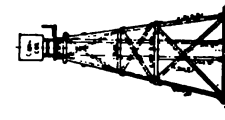


FIG. 24.—END VIEW,

Company at Cleveland, built specially for fueling the passenger steamers *Northwest* and *Northland*. The chutes in this case are round, in order to inclose the dust. The method of hauling the

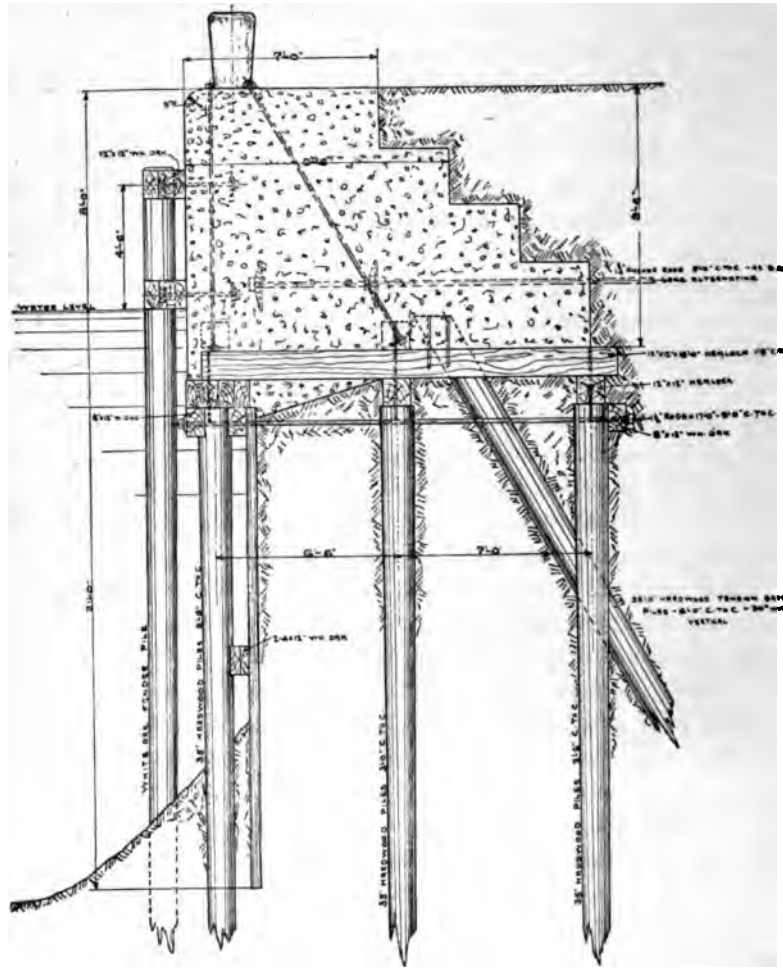


FIG. 26.—CROSS-SECTION OF ORE-DOCKS OF THE ILLINOIS STEEL COMPANY, SOUTH CHICAGO, ILLINOIS. SCALE, 7 FEET TO 1 INCH.

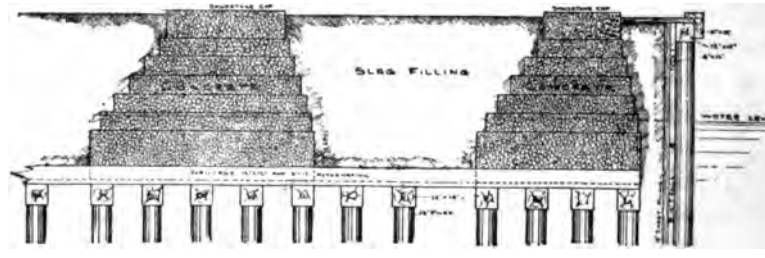


FIG. 27.—CROSS-SECTION OF FOUNDATION FOR McMYLER CAR-DUMPER AT DOCK OF THE PITTSBURG AND CONNEAUT DOCK COMPANY, CONNEAUT, OHIO. SCALE, ABOUT 10 FEET TO 1 INCH.

ment that "it is possible to take ore from the Mountain iron-mine and convert it into steel ship-plate within 10 days." While not becoming responsible for the accuracy of the last statement, quoting from the same source, the explanation is as follows: "Suppose that on the first day and night of a month 9,000 tons were mined and loaded. The second day at noon this ore could be run onto the Duluth, Mesaba and Northern Railway docks at Duluth, 80 miles from the mine, and dumped into pockets. Each of the two docks lacks 600 feet of being ½ mile long, and both have capacity for 100,000 tons of ore. In one hour, the 9,000 tons could be loaded into a Bessemer steamer and barge, 424 and 366 feet long respectively. The Bessemer fleet consists of ten steamers and eleven barges, and the carrying capacity of the fleet for one season, between eight and nine months, is over 1,500,000 tons. At 1 p.m. on the second day, the steamer and consort would start on their 890 miles trip. On the sixth day at 1 p.m., they would arrive at Conneaut, Ohio, the steamer, we will say, going to the McMyler rapid direct-unloading plant and the consort to the Brown plant. The seventh day at 1 p.m., the 9,000 tons of ore would have been taken from the holds of the vessels and loaded into 180 of the 50 tons steel cars, of which the Pittsburg, Bessemer and Lake Erie has 600 and is building 400 more. On the morning of the eighth day, these cars would be delivered to the furnace at Bessemer or Duquesne, the four-stacks furnace having an annual capacity of 800,000 gross tons of pig-iron, at the latter point. The distance from Conneaut to this furnace is about 150 miles. On the ninth day, at 7 a.m., the ore would have run through the cupola and could be transferred to the Bessemer converter or mixer, and in less than an hour be turned into steel ingots. These ingots could be taken hot to the plate-mill and made into ship plate in one hour; or if from the furnace the iron was made into pigs, some eight hours more would be required to make ingots of the pig. By the evening of the ninth day, this plate would be ready for shipment. Even if twenty-four hours for delays are added, it is shown that in ten days ore from Lake Superior can be made into plate on a larger scale than in any other country in the world, and at considerably less cost."

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

HELD AT ANSLEY HALL, NEAR NUNEATON, APRIL 7TH, 1900.

MR. MAURICE DEACON, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. W. H. HEPPLEWHITE'S PAPER ON "THE HEPPLEWHITE TAPERED PIT-PROPS AND BARS."*

Mr. J. A. LONGDEN (Stanton) said that during the last three months Hepplewhite tapered props had been used at Teversal colliery in one of the stalls which had a particularly bad roof. On one side of the gate-road, 36 tapered props had been used during the last three months; and on the other side of the same gate-road 101 ordinary props had been consumed; and the saving was over 60 per cent. He was so far satisfied with the Hepplewhite tapered prop that he had ordered special machinery for dealing with the whole of the props used in connection with their collieries; and as they used more than £10,000 worth of timber a year in their mines he anticipated that a considerable saving would be effected.

Mr. G. ELMSLEY COKE (Nottingham) remarked that he had no practical experience of tapered props, but after visiting many collieries, he found that the testimony of those who used the props strongly supported Mr. Longden's views, and all agreed that there was a saving of timber. Mr. Hepplewhite deserved the thanks of mine-owners for having so ingeniously thought out this matter.

Mr. G. SPENCER (Derby) said that Mr. Hepplewhite had unquestionably struck upon the proper principle of timbering, and he (Mr. Spencer) had proved it up to the hilt at the collieries under his charge. Before the paper was read he was using something like 1,000 steel props in the mine, and after reading Mr. Hepplewhite's paper he saw so clearly that Mr. Hepplewhite had hit upon

* *Trans. Inst. M.E.*, 1899, vol. xix., page 8.

the right principle of timbering that he had some steel props pointed, and used them in their Kilburn pit which had rather a tender roof, and a hard floor. The pointed ends penetrated from 3 to 6 inches into the hard floor and saved the roof, and this was a clear proof of the soundness of the principle. In the timbering of mines the inevitable settling of the roof must be considered, and provision made for it either by using a yielding prop, or a rigid prop which could penetrate into the floor.

Mr. J. H. W. Laverick (Pye Hill) said that they had tried tapered props in four different coal-seams, with somewhat varying results. There had certainly been a saving in the consumption of timber in the whole of the seams, but the saving was most marked where they had a rock roof and a strong floor. He could not say at the present moment what the reduction in the timber bill would be, because the experiments had not been extended over a sufficient period to enable them to draw a definite conclusion, but there could be no doubt that there was a saving. Where, however, they had a soft floor and a comparatively mild roof, naturally he had not found so great a benefit. In one stall he had found one of the ordinary props which had been in daily use for 15 months, and it was still in good condition. It was sunk into the floor from 12 to 18 inches at each setting. With a strong roof and a strong floor he was convinced that the tapered prop was the prop of the future. There was another point that was worth noting, and that was the effect that the use of tapered props had upon a heavily weighting roof. It had been observed in one district of a pit that the former heavy weighting had been less severe, which was attributable probably to the tapered props yielding to the weight and allowing a more gradual settling. The tapered props were popular with the workmen because they could much more readily be withdrawn from the waste. One workman remarked that they could be got out in a quarter of the time as compared with the old kind, and possibly he was not far out, when it was considered that the area of a 3 inches circle was one fourth of a 6 inches circle, and consequently the ground to be cut away from the foot of a prop would be in that proportion. This, of course, would apply only where the props could be released at the foot. It would be interesting to hear the result of a trial of these props in South Wales, where the timber costs were very heavy.

Mr. A. S. Douglas (Hucknall Torkard) observed that having been one of the first to use tapered props, and having had experience of their use for something like 9 months, he felt that he could speak with some degree of confidence as to their use, and as to the saving effected in the pits under his control. In one of the largest districts of the Hucknall Torkard colliery, where 1,110 Hepplewhite tapered props alone were in use, only two broken props were found on inspection. One prop had broken because the taper had been entirely worn away, and it had practically become an ordinary square-ended prop; and the second had broken at a knot, showing that the knot was weaker than the weakest part of the tapered portion of the prop. The saving resulting from the use of the tapered props had been about 30 per cent. over a period of 9 months. Of course, colliery officials must understand that in using tapered props it is indispensable to see that as soon as the taper is reasonably worn off, the prop should be sent out of the mine and re-tapered. Otherwise, they simply got back to square-ended props. He was using tapered props in some districts under a "comb coal" roof, which showed that they were capable of being used to great advantage even under a moderately tender roof. The greatest advantage, however, was gained where the floor and roof was strong. They had had no fallen stalls since tapered props were used, and that was another proof of their utility apart from the actual saving in the initial cost of timber.

Mr. H. R. Hewitt (H.M. Inspector of Mines, Derby) said that Mr. Alfred Mathieu* had described a tool of the circular-saw type for cutting and shaping the ends of timber, which seemed to show that Mr. Hepplewhite's idea was not entirely new. This tool might be of interest to Mr. Longden and other members if they intended to cut a great number of props or bars in the way described by the author.

Mr. W. H. Hepplewhite (H.M. Inspector of Mines) said that he was much obliged to all those gentlemen who had tried the props, and for the highly satisfactory statements which they had made respecting them. It was very pleasing to hear that tapered props were in every way a success. He had had to fight down during the past two years a great amount of prejudice, but now that the tapered props had been successfully tried and adopted at

* *Revue Universelle des Mines*, 1892, vol. xviii., pages 50 to 52; and *Trans. Inst. M.E.*, 1893, vol. v., page 618.

many large collieries he hoped that their adoption would become general in mines with hard floors and consequent great destruction of timber. The machine mentioned by Mr. Hewitt was a milling machine for notching a piece out of pit-timber, and shaping another piece to fit into the notch. He had fully described a suitable machine for tapering props and bars in his paper. It was on the principle of the ordinary lead-pencil sharpener, and very successfully made the necessary length of taper. It was particularly necessary that the prop should be clamped and bolted perfectly firm on the travelling-table, otherwise there was a danger of it jumping up and injuring the attendant. He could not help thinking that a circular saw would do all that was required to the end of the prop and at a small cost.

Mr. H. WALTERS (Birley Collieries) said that it was very pleasant to hear how successfully tapered props had been used in many collieries. They used nearly 120,000 props per annum. They had a shaky roof and a bad floor at the Birley collieries. He had tried pointed props and they were of no use whatever, but he intended to try them again. The tapered prop was the right thing in the right place, but unfortunately he had a pit which did not happen to fit the prop.

Mr. M. WALTON BROWN wrote that Mr. G. L. Kerr had stated in December, 1898, that "when the pavement is hard and slippery the props are often pointed, so that they will crush up when the pressure comes upon them."*

Mr. W. H. HEPPLEWHITE replied that tapered props were intended for use in mines with hard impenetrable floors. It was never intended for the pointed taper to enter soft floors.

The PRESIDENT remarked that the members were much indebted to Mr. Hepplewhite for bringing so important a matter before them. In the majority of cases in which the tapered props had been used they had apparently been successful. The subject was of such importance that with their permission the discussion would be adjourned.

The following paper on "Underground Haulage at Glapwell Colliery," by Mr. J. F. LEE, was taken as read:—

* *Trans. Inst. M.E.*, vol. xvi., pages 234-5.

UNDERGROUND HAULAGE AT GLAPWELL COLLIERY.

By J. F. LEE.

In extensively worked mines, the cost of the underground conveyance of coal is a matter requiring careful consideration, and with steep gradients it is essential to get as much as possible of the work done by mechanical appliances. To carry this out effectually in a dipping mine, the main roads in the direction of the full dip should be driven well in advance of the stall-faces, so that the haulage-ropes may be kept on the low side of the working-places, and instead of the coal having to be pulled by horses, the tubs will gravitate to the roads in which mechanical haulage is applied.

Conditions vary so greatly that no definite system can be followed: each manager adapting himself to the circumstances by which he is surrounded, and gradually building up the system best suited to his particular case. Where the roads are fairly straight, and can be economically maintained as double roads, it is generally admitted that the endless-rope method is more economical than the main-and-tail rope system. In some mines, the nature of the roof will not allow of the width required for a double line of tramroad; the question then arises whether it is better to maintain two single roads or to place the endless rope on a single road with pass-byes.

Comparatively slow speeds tend to reduce wear-and-tear to a minimum, but this can be carried out to advantage only within certain limits. For instance, if an engine so constructed as to give a direct pull equal to 150 horsepower be applied to a hauling-rope running at the speed of 1 mile an hour, it will be necessary to provide for a safe working-load of 25 tons, whereas if the same power be applied to drive a hauling-rope at 2½ miles an hour, it will be requisite to provide only for a safe working-load of 10 tons. A rope equal to this strain, and made of the best plough-steel wire, is sufficiently heavy for handling at the junctions when worked on the top of the tubs.

In steep mines, equipped with endless rope, it is generally better to carry the rope on the top rather than under the tubs. In seams where the roads undulate and the junctions are numerous, a bottom rope can be applied with advantage. The writer worked a system of endless-rope haulage with an under rope in a mine with undulating roads, no coupling-chains were used on the tubs, and the draw-bars were made suitable for a clip-attachment, the tubs being worked singly on all the rope-roads. In a bord-and-pillar mine, by this system of haulage, there is no difficulty in working junctions on any part of the road.

With heavy gradients and the rope on the top of tubs the chain-fastening for attaching the tubs to the rope is a sure one, but more difficulty is experienced at the junctions of branch roads.

It is proposed in this paper to describe the system of haulage in use at Glapwell colliery, where the rope is worked on the top of the tubs in the steepest part of the workings and below the tubs, where that system can with advantage be applied.

The Top Hard coal-seam is 900 feet from the surface at the shaft, which is sunk on the dip side of the anticlinal of the Coal-measures. The seam at the shaft dips to the east at a gradient of 1 in 5, gradually decreasing to 1 in 12. The output, of about 10,000 tons a week, is hauled to the pit-bottom along three main roads by three steam-engines placed on the surface. Three-fourths of this quantity is brought from the districts on the dip side of the shaft by two main roads, known as the old and new engine-planes, driven to the full dip in parallel lines for a distance of 2,235 feet, the old engine-plane being continued for a further distance in a straight line of 1,600 feet (Fig. 1, Plate III.).

The engines for the old and new engine-planes stand side by side in the same engine-house, and are controlled by one engine-man. The right side or new engine-plane engine has one cylinder 26 inches in diameter and 3 feet stroke. The crank-shaft, of hammered scrap-iron, is 10 inches in diameter, the second-motion shaft 11½ inches in diameter, and the third-motion shaft 13½ inches in diameter. The gearing is in the proportion of 2·8 to 1, between the first and second motion-shafts, and 2·71 to 1 between the second and third motion-shafts, giving 7·6 revolutions of the crank-shaft to 1 of the driving-shaft. The first pinion and spur-wheels are 12½ inches wide, with teeth of 4 inches pitch, the second

pinion and spur-wheels being 14 inches wide, with teeth of 4½ inches pitch. The rope-driving wheel is 7 feet in diameter, and the speed of the piston in proportion to that of the rope is as 2·07 to 1. The engine indicates 153 horsepower (Fig. 2, Plate III.).

The left side, or old engine-plane engine, has a single cylinder, 26 inches in diameter and 3 feet stroke, the crank-shaft is 10 inches in diameter, the second motion-shaft 11½ inches in diameter, and the third motion-shaft 13½ inches in diameter. The first pinion and spur-wheel are 12½ inches broad, with teeth of 4 inches pitch; the second pinion and spur-wheel, 14½ inches broad, with teeth of 4½ inches pitch. The ratio of gearing from the first to the second motion-shaft is 3 to 1, and between the second and third motion-shafts, 3·35 to 1; and this is equal to 10 revolutions of the crank-shaft to 1 of the rope-wheel. The diameter of the rope-driving wheel is 9½ feet, and the relation of the piston-speed to the rope-speed is as 2·01 to 1. The engine indicates 153 horsepower (Fig. 2, Plate III.).

The old engine-plane rope, 11,400 feet long and 4 inches in circumference, is made of plough-steel, the details of the rope being as follows:—Lang lay; 6 strands, each containing 9 wires of No. 11 Birmingham wire-gauge and 7 wires of No. 15 Birmingham wire-gauge. It is passed three-and-a-half times round the driving-wheel, covered on the tread with cast-steel liners, which can be renewed whenever necessary (Fig. 3, Plate III.).

The rope is taken down the upcast shaft, the pulleys at the top and bottom being cast-steel, 6 feet in diameter: it is then carried to the far end of the main road, where it is passed three-and-a-half times round a C pulley, *A*, placed on a vertical shaft, by which the No. 4 slant district or branch-rope wheel is driven. The rope is next passed round the return-wheel, *B*, which works as a tension-pulley, to adjust the varying length of the rope caused by the undulation and difference in the load (Figs. 4 and 5, Plate III).

The No. 4 slant district or branch rope, 7,050 feet long, 3 inches in circumference and made of improved steel, is passed round the driving-wheel on the same shaft as the main-rope wheel, *A*, and controlled by a claw-clutch and brake. A friction-clutch was used, but, in practice, it was found to cause stoppages and breakages by being put in and out of gear with the main rope in motion. Before the claw-clutch can be put in or out of gear the

main rope must be stopped, and in this way the difficulty is overcome. A tension-wheel, *C*, is fixed on a moveable bogey at right angles to the branch-road to take up the slack of the off-coming rope. The pedestals of the return-wheel, *D*, at the terminus, are laid on rails, so that the wheel can be adjusted by a screw to take up the slack rope from the tension-wheel when required.

The coal from No. 3 south district is attached to the main rope at No. 4 slant district junction (Fig. 4, Plate III.).

The new engine-plane rope, 7,800 feet long, is of the same quality, size and construction as the old engine-plane rope. This is also passed round the engine driving-wheel three-and-a-half times and carried to the far end of the new engine-plane, then passed round the wheel, *E*, at the No. 3 slant district junction on the same shaft, from which the branch-rope wheel is driven. The main rope is then taken round the tension-wheel, *F*, which for convenience is placed at right angles to the line of the main engine-plane (Fig. 1, Plate III.). The No. 3 slant district rope, 7,500 feet in length and 3 inches in circumference, is driven from the main rope in the same manner as described for No. 4 slant district haulage.

Junctions are made where required on the branch-road by using a hanging pulley to suspend the full rope, so that full and empty tubs may pass underneath (Figs. 6, 7 and 8, Plate III.). When the person in charge of the junction intends to hang on full tubs or detach empty tubs he puts the rope into the hanging pulley by taking advantage of the passing full tubs which hold up the rope. A bell, placed about 150 feet away from the junction, is automatically rung by the tubs, and gives ample warning that the rope must be taken out of the wheel before the tubs arrive.

Wheels with broad bottom flanges (ribbed so as to point off the lashing chains being carried over them, and fixed horizontally with one pulley on each side of the rope) have been tried with the idea of working without liberating the rope from the wheels, and so that the lashing-chains would travel past with the tubs and yet maintain the rope in the position for the branch-road tubs to pass underneath at any time (Figs. 9, 10 and 11, Plate III.), but in practice it has been found that the vertical-pulley arrangement is most suitable (Figs. 6, 7 and 8, Plate III.).

There is a junction on the new engine-plane, 1,680 feet from the top, where the coal from the north and No. 1 slant districts is attached. No. 1 slant district haulage is worked by an engine, with two cylinders, 12 inches in diameter, driven by compressed air, which is also being applied to the north district. As this junction will in all probability be used for some years, and the output will reach 400 tons a day, the road on the main line has been made level for a distance of about 60 feet, to allow of the full and empty tubs passing underneath the rope without the use of overhead pulleys (Figs. 14 and 15, Plate IV.).

On the main engine-planes, and also on No. 3 and No. 4 slant districts branch-roads, the full tubs are attached to the rope in couples by a lashing-chain, 11 feet in length, made of iron $\frac{3}{4}$ inch in diameter. There is a hook at each end of the chain, one of which is attached to the tub-coupling, the other end is passed three or four times round the hauling-rope, and is secured by a hook (Fig. 22, Plate V.).

The empty tubs, in batches of 6 or 8, are attached with a lashing-chain in front and another on the last tub.

Checks, or "idlebacks," formed of old rails, are fixed at intervals of 90 or 120 feet to switch the full tubs on to the road when from any cause they may get off. Pieces of coal are sometimes pushed off the tubs by the rope and cause accidents, but the loading is done as far as possible by fixing large pieces of coal at the ends of the tubs so as to prevent this. Check-rails are laid on the inside of each rail of the empty way to prevent the tubs from leaving the road (Figs. 16, 17, 18 and 19, Plate IV.). Before check-rails were used, the weight of the rope sometimes swayed the tubs off the road, but the check-rail, which is made out of chair rails, effectually gets over this trouble.

Figs. 12 and 13 (Plate III.) show an hydraulic machine used for testing the lashing-chains. Every chain is tested up to a working-load of 1 ton, and the machine is so designed that not more than this strain can be applied. Accidents were frequently caused by faulty chains, which the precaution of testing had to a great extent obviated. The machine is fixed at a convenient place between the engine-planes, and the power for working it is obtained

from the water-pipes conveying fresh water from the surface to the underground stables.

The full tubs from the new engine-plane are landed at the level of the bottom-deck of the cage, and those of the old engine-plane at the top-deck level, but in case of stoppage on either of the engine-planes the tubs can be taken to either deck by means of an hydraulic hoist, which is also used for lowering the tubs. The hoist, or cage, has a tilting bottom. If the tubs are required to be sent from the lower to the higher level, the boy in charge of the hoist and running on the tubs can control the ram, and when the cage reaches the top-deck level, the rails tilt automatically, causing the tubs to run off; these in turn strike a lever, which relieves the water-pressure and allows the cage to return. When the full tubs are required to be dropped to the lower level, the boy on the top-deck controls the arrangement in a similar manner (Figs. 20 and 21, Plate IV.).

The empty tubs from the top-deck are run from the shaft to the lower level in sets by a balance-chain passed over a pulley, with a brake-attachment; and all the empty tubs from both decks are then taken by a separate road on a slightly dipping gradient to the main engine-planes (Figs. 23 and 24, Plate V.).

The haulage-ropes are worked at a speed of from 2 to 2½ miles an hour, this being found to be the highest speed that can be worked and still allow of the tubs being detached at the junctions and at the bank-heads at the shaft.

The Hardwick or south side districts haulage is effected by an engine having cylinders 16 inches in diameter and 3 feet stroke, geared in the proportion of 8·8 of the crank shaft to 1 revolution of the rope-driving wheel, the power under ordinary working conditions being 24 horsepower. The driving wheel is 7 feet in diameter, and the ratio of the speed of the rope to the speed of the piston is as 1 to 2·4. This engine is larger than necessary for the present work, but its full power will probably be required in the future. This rope is also taken down the upcast shaft and passed round wheels, 6 feet in diameter (Fig. 1, Plate III.).

The tension-wheel, *G*, is placed near the bottom of the downcast shaft, but it necessitates a heavier weight on the moveable

carriage than would have been required had it been placed nearer the shaft down which the ropes are taken (Fig. 1, Plate III.).

The engine-plane for a distance of 1,575 feet is level. A dip-fault is then met with, which alters the gradient to 1 in 8 for a distance of 330 feet; and from this point the road dips to the far end at a gradient of 1 in 30.

The haulage on this section is worked by a bottom rope, made of improved steel, 9,600 feet long and $2\frac{3}{4}$ inches in circumference. In the first length of 1,575 feet the tubs are worked in sets of from 20 to 30 tubs at one time, with a lever-clip (Figs. 25 and 26, Plate V.). A clip-boy walks along with the set. Beyond this distance, screw-clips (Figs. 27 and 28, Plate V.) are used on the heavy gradient, hauling from 4 to 6 tubs at one time, and the lever-clip is again brought into use at the far end.

The main road next the face cannot be maintained of sufficient width for the last 1,000 or 1,500 feet until the goaf settles, and for this distance a single road only is used with both ropes carried between the rails. One clip-boy, with a lever-clip, works the traffic, by attaching the tubs to either rope as required.

The following is the cost of labour of working the haulage on the rope roads only:—

New engine-plane ...	1·659d.	per ton, or	1·518d.	per ton per mile.
Old engine-plane	1·267	,,	0·937	,,
Hardwick engine-plane	1·396	,,	2·469	,,

The Hardwick district is not yet fully developed, and the cost incurred is sufficient for a larger output.

The cost of ropes for the main dip engine-plane is 0·702d. per ton per mile, and for branch-roads 0·344d. per ton per mile. The Hardwick engine-plane has not worked sufficiently long to enable the writer to state the cost.

The number of tubs in use is 1,710, and of this number 50 are of steel and 1,660 of wood (Figs. 29, 30, 31, 32, 33, 34, 35 and 36, Plate V.). The cost of maintaining the tubs is high, compared with a level mine, and for 12 months was as follows:—

Material	£1,233	15	6
Machinery	21	0	0
Wages	421	6	11
Total cost	£1,676	2	5

During last year, this cost reached 0·88d. per ton. The steel tubs have only been in use for a few months. The same outside dimensions as the wooden tubs give an average carrying capacity of 11 cwts., or 1 cwt. more than the wooden ones. A separate account is kept of the cost of these repairs, so as to enable a comparison to be made later on.

Oaken frames have been fixed to some of the steel tub-bodies, and a trial is being made with flat steel frames, 5 inches by ½ inch, turned so as to form buffers (Figs. 33, 34, 35 and 36, Plate V.).

When the spur-wheels of the right side or new engine-plane hauling-engine were comparatively new, the engine having only been run for a few days, the writer made some trials to determine the proportion of horsepower utilized in moving the load, that absorbed in the engine and gearing, and that expended in friction of the rope and the rope-wheels. On the outcoming or loaded rope of the new engine-plane, between the north district junction and the shaft, 70 full tubs were attached by lashing-chains in couples in the usual manner, at intervals of about 60 feet, and 18 tubs were placed on the ingoing rope. Indicator-diagrams were taken, the positions of the full and empty tubs recorded, and the gradients noted. All the tubs were weighed, and also tested to ascertain the friction of the wheels. The co-efficient for the full tubs was found to be as 1 to 56; and the co-efficient for the empty tubs as 1 to 30. From the weight of the load due to gravity and the friction of the full tubs, a deduction was made for the weight of the empty tubs due to gravity less the friction. The rope was taken off the driving-wheel, and indicator-diagrams taken, which showed that a mean pressure of 2·79 pounds per square inch on the piston was required to drive the engine and gearing at the normal speed. The power necessary for the load, friction of engine and gearing, rope and rope-wheels, resulting from the average of two experiments, was found to be as follows:—

	Per cent.
Proportion of indicated horsepower for load	83·26
,, ,, for engine and gearing	10·28
,, ,, for rope and rope-wheels	6·46
	100·00

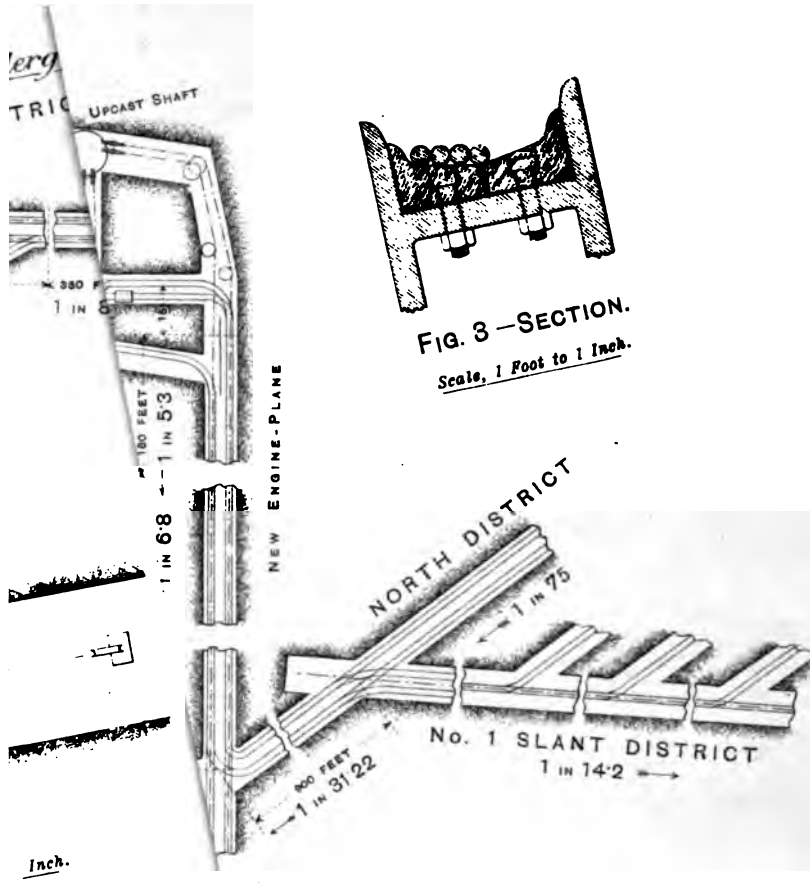
The details of the foregoing trials are contained in the Appendix.

APPENDIX.—RESULTS OF EXPERIMENTS MADE WITH THE NEW ENGINE-PLANE HAULING-ENGINE AT GLAPWELL COLLIERY, TO ASCERTAIN THE LOSS IN FRICTION OF ENGINE AND GEARING, FRICTION OF ROPE AND ROPE-WHEELS AND THE POWER UTILIZED IN MOVING THE LOAD.

	Experiment No. 1.	Experiment No. 2.
Diameter of cylinder, 26 inches.		
Length of stroke, 3 feet.		
Diameter of driving-wheel, 9½ feet.		
Proportion of gearing, 7¼ to 1.		
Diameter of rope-driving wheel, 9½ feet.		
Relation of piston-speed to rope-speed, 1·508 to 1.		
Revolutions of engine per minute	35	35
Mean pressure, in pounds per square inch, with load ...	26·63	27·58
Mean horsepower, with load	89·97	93·18
Mean pressure, in pounds, per square inch, engine and gearing only	2·79	2·79
Mean horsepower, engine and gearing only	9·42	9·42
Number of full tubs attached to the rope on each section of the road—		
Gradient, 1 in 5·93	8	—
,, 1 ,, 6·16	—	20
,, 1 ,, 7·18	30	32
,, 1 ,, 8·11	32	—
,, 1 ,, 8·46	—	18
Number of empty tubs on the rope	18	18
Gross weight of full tubs ... ... tons	54·65	54·65
Weight of full tubs due to gradient ... ... ,,	7·40	7·68
Add for friction of full tubs, 1 : 56 ... ... ,,	0·97	0·97
Weight of full tubs, load for gravity and friction ,,	8·37	8·65
Gross weight of empty tubs ... ... ,,	4·50	4·50
Weight of empty tubs, due to gravity ... ... ,,	0·65	0·54
Less for friction of empty tubs, 1 : 30 ... ... ,,	0·15	0·15
Deduct from full tubs, load for weight due to empty tubs ... ... ,,	0·50	0·39
Weight of load on engine ... ... ,,	7·87	8·26
Total strain on piston, as calculated from indicator-diagrams ... ... ,,	6·31	6·54
Theoretical strain on rope ... ... ,,	9·51	9·86
Proportion of power required for moving load, per cent.	82·75	83·77
Proportion of power required to drive engine and gearing ... ... ,,	10·47	10·10
Difference being friction of rope and rope-wheels ... ... ,,	6·78	6·13

FIG. 3.—SECTION.

Scale, 1 Foot to 1 Inch.



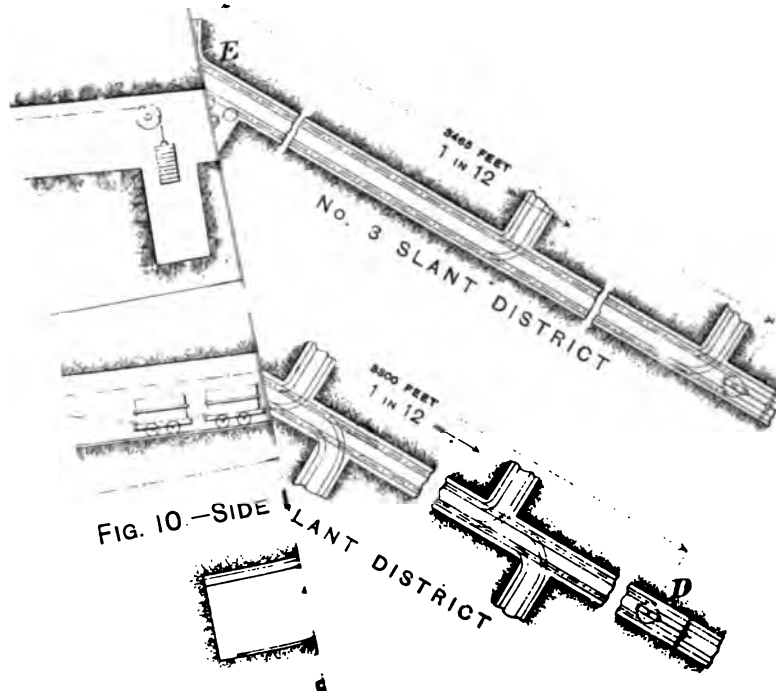


FIG. 10.—SIDE [illegible] LANT DISTRICT

FIG. 11.—END

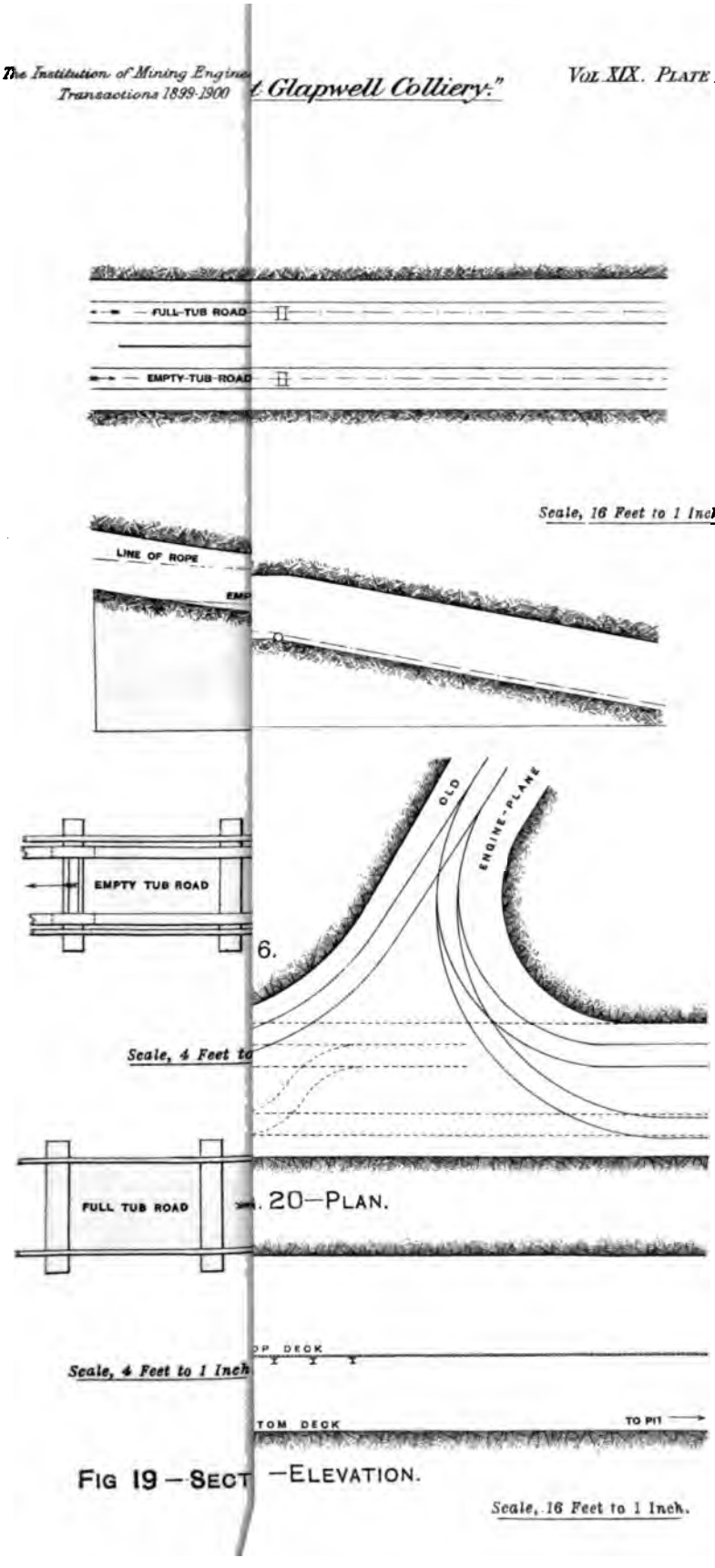
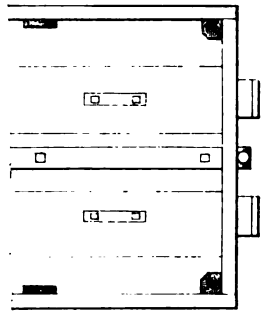

FULL-TUB ROAD
EMPTY-TUB-ROAD
Scale, 16 Feet to 1 Inch.
LINE OF ROPE
EMP
OLD
ENGINE-PLANE
EMPTY TUB ROAD
6.
Scale, 4 Feet to
FULL TUB ROAD
20—PLAN.
DP DECK
Scale, 4 Feet to 1 Inch
TOM DECK
TO PIT
—ELEVATION.
Scale, 16 Feet to 1 Inch.

FIG 19—SECT



9.—Plan.

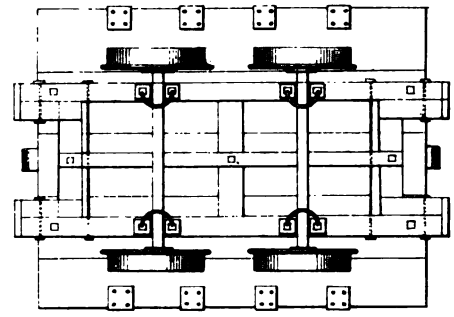
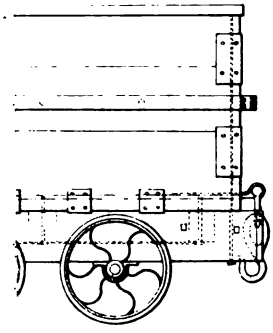


Fig. 30.—Plan of Bottom.



IDE Elevation.

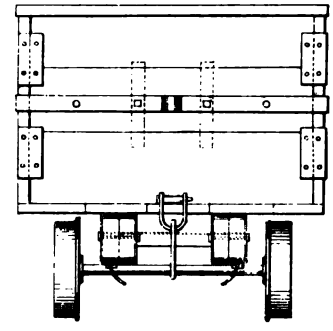
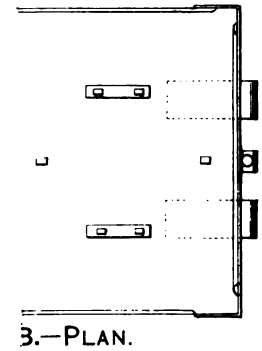


Fig. 32.—End Elevation.



3.—Plan.

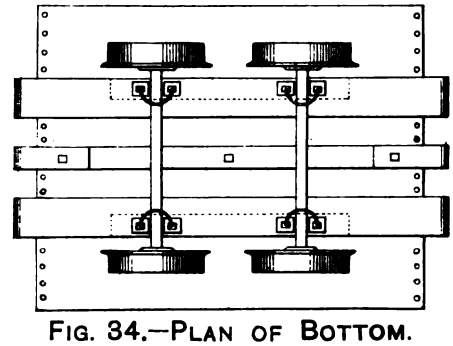
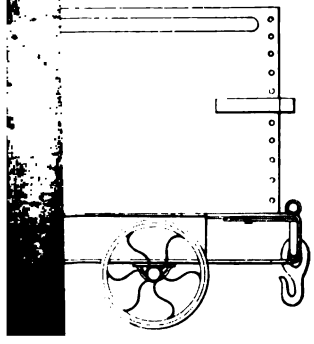


Fig. 34.—Plan of Bottom.



E Elevation.

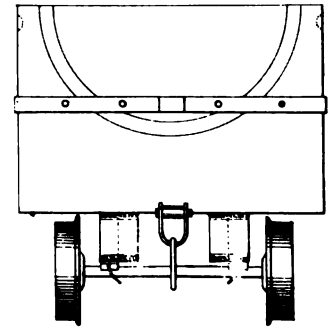


Fig. 36.—End Elevation.

Scale, 2 Feet to 1 Inch.

DISCUSSION OF MR. J. A. LONGDEN'S PAPER ON "COLLIERY CONSUMPTION."*

Mr. W. Price Abell, referring to Mr. Longden's remarks "that colliery consumption does not occupy that place in the mind of mining engineers that it should do," said that a chord had been struck that could not be sounded too loud or too often. After ten years' practice as a consulting engineer in charge of factories, using 80 boilers with over 1,200 square feet of heating surface each, in a colony where fuel put in the furnace cost between £2 and £3 per ton, nothing struck him on his return to the Old Country so much as the enormous loss in fuel and the disregard of economics that would prevent this. Of course the cause of this waste is the low price of low-class fuel at collieries. For a successful diagnosis, the first thing is to determine a fairly standard system of comparison; this, as Mr. Longden pointed out, would have to be very carefully laid down, so that the varying conditions of the different collieries would be covered by the system. On the estates with which he had been connected the fuel consumption was standardised, and, after the financial statements, occupied the second position in the monthly and half-yearly returns of the factories and always received very pertinent attention from all in authority. This standardised fuel consumption developed into a fairly universal practice about the year 1887. The fuel consumption at that time averaged 27 cwts. per ton of produce made, varying of course with the quotient of veracity of the respective managers and attorneys. As the system was developed and statements qualified, certain heart-rendings naturally took place; but the nett result since then had been that the 27 cwts. has been reduced to 5 cwts. of coal required, in this instance amounting to a reduction in fuel cost of considerably over £2 per ton on the produce made.

Having stated that a system is necessary for diagnosis, besides acting as a stimulant to this economy, he would now proceed to look at a few items which this system enabled the pruning hook

* *Trans. Inst. M.E.*, vol. xvi., page 366; vol. xvii., page 253; vol. xviii., page 145; and vol. xix., page 50.

of economy to attack, only paying attention to those points applicable to collieries:—

(1) The utilization of exhaust steam and parting with it at a temperature of not more than 110° Fahr., and as the average atmospheric temperature there was 80° Fahr., this meant a loss of only 30° Fahr.

(2) Higher steam pressure.

(3) Discarding obsolete, and adopting more efficient machinery.

(4) A very great attention to and improvement in the furnaces, whereby waste material was utilised as fuel; indeed every manager latterly began to look at his chimney as an indicator; the amount of information that can be obtained from careful observation of the chimney is really surprising.

Mr. Longden had not exaggerated, in the least, the importance of the correct amount of air necessary for combustion, as too much or too little meant waste, and too much air was responsible for the greater losses. A cultivated observation of chimneys detects this waste, and it is easier to draw conclusions from the top of the chimney-stack than it is to forecast weather from the atmosphere. Mr. Longden gave no data bearing on the result of using hot *versus* cold air. He had built over 200 furnaces, over 100 using hot air for burning a saw-dusty kind of waste fuel containing 50 per cent. of water, in the latter the hot air was found to increase the efficiency about 20 per cent. The air was raised to a temperature of 300° Fahr., in some cases by passing it over the boiler, and in others by simply passing it round the furnace brickwork.

(5) Preventing loss of heat from pipes and boiler-houses by lagging the former and roofing the latter; and last, but not least, avoiding every bend and foot of pipe not absolutely necessary, carefully draining the same.

(6) A very marked improvement in the condition in which machinery was kept, both outwardly to the eye and internally. In the latter instance, leaking pistons and valves account for much waste. To the ordinary engineer, the indicator-diagram does not show these latter leaks.

Nothing indicates the successful running of a steam-plant so much as a low fuel consumption. Again, nothing is so conducive to the efficient up-keep of the whole of the machinery as a low fuel consumption. Nothing stimulates manager and engineer in charge to look for detailed efficiency so much as low-standard fuel

consumption. Indeed a qualified low consumption is one of the surest indicators of successful work all round. Finally, to corroborate the importance of Mr. Longden's paper, he could not do better than quote from his paper that "the annual saving thus effected amounting to more than £100,000."*

HAUNCHWOOD COLLIERIES.

Tunnel Mine (New Colliery), Ansley.

The downcast shaft is 16 feet in diameter and 1,155 feet deep. The winding engine has two horizontal cylinders, 32 inches in diameter by 5½ feet stroke, and is fitted with Eatock slide-valves.

The upcast shaft is 15 feet in diameter and 1,155 feet deep. The winding engine has two horizontal cylinders, 32 inches in diameter by 6 feet stroke, and is fitted with trip-gear and Cornish valves.

The underground haulage in the south and west districts is on the endless-rope system; the rope is driven by an engine, on the surface, with two horizontal cylinders, 22 inches in diameter by 3½ feet stroke; and in the north district, the endless-rope is driven by an horizontal engine, in the pit, with two cylinders, 16 inches in diameter by 32 inches stroke.

There are 9 Lancashire two-flued boilers, 8 feet in diameter by 30 feet long, working at a pressure of 100 pounds per square inch, fired with dust slack.

The Nine-feet and Two-yards seams are being worked, and the coals are cleaned on picking-belts and screens.

The surface and pit-landings are lighted by electricity supplied from an Ellwell-Parker dynamo, driven by a high-speed vertical engine. There is a high-speed air compressor supplying air to coal-heading machines and coal-cutters.

Haunchwood Mine (Old Colliery), Stockingford.

The downcast and upcast shafts are 630 feet deep, and the winding-engine has two horizontal cylinders, each 25 inches in diameter by 4½ feet stroke.

* "Megass and Refuse-furnaces," *Minutes of Proceedings of the Institution of Civil Engineers*, 1895, vol. cxxiii., page 369.

Electric power is supplied from a dynamo of 170 kilowatts driven by an engine with two horizontal cylinders, 22 inches in diameter by 3½ feet stroke, and by 14 cotton-ropes, each 1¼ inches in diameter.

There are 7 Lancashire and two egg-ended boilers, fired with dust fuel.

The Nine-feet and Two-yards seams are being worked, and the coal is cleaned on picking-belts and screens.

The main-incline haulage endless-rope is driven by an electric motor of 100 horsepower; and the level haulage endless-rope is driven by an electric motor of 20 horsepower.

There are 2 three-cylindered electrically driven pumps, 5 and 4 inches respectively in diameter, in the mine; and a 12 inches bucket-lift worked by an engine on the surface.

The ventilation is produced by an open-running Capell fan, 11 feet in diameter.

ANSLEY HALL COLLIERY.

The pits are sunk on the bassitt of the royalty and intercepting the Ryder seam at a depth of 204 feet are sunk below this seam to a depth of 504 feet. The Ryder seam is then won by a crut or measures-head, 975 feet long, driven from the shaft to the deep of the measures. The No. 1 pit is 8 feet in diameter, the No. 2 or winding pit is 13 feet in diameter, and the No. 3 or upcast shaft is 13 feet in diameter.

From the far-end of the No. 2 measures-head, the Ryder seam is developed by an incline, 3,840 feet long, with an average inclination of 1 in 4. From the top of No. 3 measures-head, the Ryder seam is developed by means of an incline, driven on the dip of the seam, 2,640 feet long, with an average inclination of 1 in 2, the highest inclination being 33 degrees. The haulage on both these planes is by endless rope, worked by engines placed on the surface. The haulage on the levels is by endless rope, driven by electric-motors, no horses being employed.*

The winding-engine has two horizontal cylinders, 22 inches

* *Trans. Inst. M.E.*, vol. iii., page 847.

from a well for use in the district. Indiarubber single cables are used, and also a lead-armoured concentric cable. A vertical engine and electric generator supplies current to the electric lamps.

A Hathorn-Davey horizontal engine, with a cylinder 24 inches in diameter by 3½ feet stroke, works a 7 inches double-acting ram, pumping from the bottom in one column to the surface.

The screening and sorting plant comprizes a travelling belt, 3 feet wide and 270 feet long, from which large coal is selected, and the residue taken by an elevator to a rotary screen, 4½ feet in diameter and 21 feet long. The plant is driven by a horizontal engine, 12 inches in diameter by 2 feet stroke.

There are five Lancashire boilers, 30 feet long and 7½ feet in diameter, working at a pressure of 80 pounds per square inch.

The whole of the spoil, sent out of the pit, is made into bricks by a Bradley and Craven machine capable of an output of 1,300 per hour. The bricks are taken to the kiln from the machine and are burnt with dust or smudge coal. The plant makes 3,000,000 saleable bricks per annum.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JULY 21ST, 1900.

MR. H. S. STRATTON IN THE CHAIR.

Mr. N. M. THORNTON read the following paper on "Longwall Methods in the Eastwood District, Nottinghamshire":—

LONGWALL METHODS IN THE EASTWOOD DISTRICT, NOTTINGHAMSHIRE.

BY NORMAN M. THORNTON.

Eastwood is a small town situated in the west of the Nottinghamshire coal-field, about 9 miles north of the city of Nottingham.

Geology.—The Coal-measures on the eastern side of the district are overlain by Permian Limestones. These run out towards the west, from which locality they have possibly been removed by glacial action. The coal-seams lie deepest near the eastern boundary of the district, and the general dip of the strata is 1 in 20 in that direction.

The following section exhibits the succession of strata in descending order:—

	Thickness. Feet.	Ins.	Depth from Surface. Feet.	Ins.
Permian rocks -				
Magnesian Limestone	20	0	20	0
Marls and Sandstones	336	0	356	0
Middle Coal-measures—				
Strata	607	6	963	6
Coomb Coal-seam	2	6	966	0
Strata	0	9	966	9
Top Hard Coal-seam	5	3	972	0
Strata	356	10	1,328	10
Deep Soft Coal-seam	3	2	1,332	0
Strata	18	0	1,350	0
Lower Hard Coal-seam	3	0	1.353	0*

* The strata to the Kilburn coal-seam have not been proved, except at a faulted place, where the seam was found only 2 feet 8 inches thick.

Top Hard Coal-seam.—The bottom portion of the seam consists of a band of cannel coal 17 inches thick; the entire seam (5 feet 3 inches thick) is perfectly clean, and contains no dirt-bands. It is extensively worked on the longwall system.

The gateroads, 11 feet wide, are made 120 feet apart, and are supported by pack-walls, 12 feet thick, on either side. In those districts of the seam, where stone is more plentiful, additional pack-walls, 6 feet wide, are built between the gateroads. The roof is good sound shale, easy to rip and with a tendency to bend towards the goaf without fracturing. About 2 feet 9 inches of this shale is taken down in the gateroads, usually without the assistance of explosives, and these canches or "lips" are kept within 9 feet of the working-face. Owing to the excessive pressure, the roads become squeezed and narrow, and require to be side as well as top-ripped. The roof subsides more or less quickly, but after a second ripping it stands firmly without requiring to be supported by timber.

Cross-gateroads are driven 800 feet apart at an angle of 50 degrees to the main roads, and the pointed ends of their pack-walls are secured by V shaped chocks built of soft wood.

The gateroads are laid with double way, for a distance of 180 feet from the working-face, and flat-sheets are used to form turn-tables for the tubs. A tram-line is laid along the working-face, and is shifted forward as the face advances; it is only of a temporary nature, the rails being held in position by notched wooden sleepers.

The seam is holed or undercut to a depth of 5 or 6 feet, and the holing only measures 18 inches in height at the highest point. The holing is made partly in a thin fire-clay, which underlies the seam, and partly in the coal. The quantity of small coal made during holing is insignificant, and after it has been mixed with the fire-clay débris, to reduce to a minimum the risk of spontaneous combustion, it is thrown into the gob among the larger stones of the packing.

Holing commences in the early morning, and the coal, when undercut, is supported by sprags, set not more than 6 feet apart. After some hours have elapsed, advantage is taken of the great pressure which has been brought to bear upon the under-clay at the back of the holing; the fractured stone is removed and often 6 or 7 inches is added to the depth of the holing. The sprags are then withdrawn, two at a time, and the coal falls in huge masses, which are broken into convenient lumps and loaded into tubs.

At the face, the roof is supported by three rows of stout Norway props set 4 to 5 feet apart, and fitted with head-trees and tail-trees. When necessary the row of props next the gob is drawn by a chain and lever. No timber is allowed to be lost, and a fine of 3d. is imposed for each prop left in the goaf.

The Coomb coal (2 feet 6 inches thick) is removed in the gateroads, during the second ripping, and being (like the Top Hard) a good house-coal, it is sent to bank. When the goaf settles, and the district boundary has been reached, this Coomb coal is worked by the longwall retreating method, and the coals are conveyed along the old gateroads, previously constructed in the Top Hard seam.

Safety-lamps are used in both of these seams, and no blasting is required to blow down the coal, after it has been holed.

Deep Soft Coal-seam.—This seam measures from 3 feet 2 inches to 3 feet 8 inches in thickness, and is mostly worked during the winter months.

The gateways are driven 132 feet apart, and supported by pack-walls 12 feet wide, with intermediate pack-walls, 6 feet thick.

The holing is made in two dirt-bands and 3 inches of coal, and is supported by sprags set 4 feet 6 inches apart. No blasting is permitted in the coal. The method of getting the undercut coal is the same as that adopted in the Top Hard coal-seam.

Two rows of timber are set to support the roof: the foremost row of props carries planks running at right angles to the face, with one extremity notched into the coal.

Lower Hard Coal-seam.—This seam, 3 feet thick, is worked on the same general lines as the Deep Soft Coal-seam. Safety-lamps are used in the Deep Soft and Lower Hard coal-seams, and blasting is only permitted in the gateroads.

A great factor in the success of this longwall working, which applies to all the seams already mentioned, is the keeping of the working-face as near end-on or face-on as possible: thus securing the most regular shape and size of coal, and avoiding the production of small coal, which is of little value. This factor of course necessitates keeping the face in as straight a line as possible, and of producing an even settling of the weight on the pack-walls.

Labour.—The labour arrangements are upon the butty system. Three contractors or stallmen usually rent a gateroad or stall, and having a superior position to the other workmen they are, or should be, chosen from the most experienced and skilled workmen. The contractors are paid a tonnage price and provide all labour required in their stall, usually including 2 loaders, 2 stonemen, 1 dayman, 2 holers, and 1 boy. This system provides suitable employment for young men and youths, and enables them to gain practical experience. The employment consists of holing or undercutting the coal by piece or stint or by day's wage; or of day-work, which may include loading the coal, throwing back dirt into the goaf, and building pack-walls. The contractors do all work requiring skill and judgment, such as setting and drawing timber, taking down coal after it has been holed, and blasting.

The second and succeeding rippings in the gateroads are performed by "master-men," or shifters, who go into the mines at night.

Ventilation.—A scale of air flows along each gateroad, and by placing a hurdle-cloth across the road it is conducted into the cavity, formed by the "lip" which might form a receptacle for gas; and, as an additional precaution, a safety-lamp is suspended on the inbye-side of the hurdle-cloth, as near to the roof as

possible. Although the ventilation rarely permits gas to accumulate, its presence in such a position, would at once be detected from the tailing of the flame, by the men working in the gateroads. Officials frequently travel along the working-face during the shift, and test every "lip" and break in the roof for fire-damp.

Faults, etc.—Faults are practically unknown in this district, even hitches are seldom encountered in the workings, and the seams vary but little in quality and section over large areas.

Occasionally small anticlinal ridges traverse an area in a north-westerly and south-easterly direction. These irregularities interfere but little with the mining-operations, beyond requiring a few crooked gateways to be made in the synclinal hollows.

Subsidences.—While several of the shafts were being sunk some difficulty was experienced in dealing with feeders of water, which permeated through the fissures in the Coal-measure sandstone from a large water-reservoir. It has been found that the whole of the coal can be safely removed from under the reservoir; and little water is encountered during the operation, beyond a small feeder which is utilized to spray the roads of the mines.

A seam 600 feet below the surface, is being worked under one end of a water-reservoir, which is 1 mile long. The bottom of the reservoir has subsided in a gradual wave, leaving a dry tract of ground at one end of the reservoir. After the seam has been removed, the surface subsides so regularly, that ultimately it is expected the reservoir will assume its former shape.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON,
JUNE 14TH, 1900.

MR. H. C. PEAKE, PRESIDENT, IN THE CHAIR.

The PRESIDENT delivered the following address:—

PRESIDENTIAL ADDRESS.

BY H. C. PEAKE.

I appreciate most fully the honour of being your President; from several points of view, however, my position is a difficult one. In the first place, there are so many others who are more entitled to the honour, and next, there have been so many Presidential addresses, that there is practically nothing left to be said which can, in the slightest sense be considered novel, and the greater part of the few remarks that I have to make are merely recapitulations of what has been said by one or other, who have previously held the office of President of this or other institutions of which it is made up.

My predecessor, Mr. J. A. Longden, in his address last year, rather alarmed us by the pessimistic view he took as to the time during which coal would last in England; certainly, the output and consumption are increasing by leaps and bounds,—in my short experience, three-fold,—and the average rate of increase is now quite as great as in my earlier days. I am not disposed, however, to take so gloomy a view, although at the same time it behoves us to take stock of our position.

For many years coal has been abnormally cheap, and consequently, less has been done to economize its consumption than would otherwise have been the case. The present higher price is already originating efforts in the way of economy, and for

this there is ample room. The probability is that if it could be accurately ascertained, on an average, less than 10 per cent. of the theoretical power contained in the coal consumed is utilized, and although it will never be possible to utilize anything like the whole theoretical heat, even an additional 5 per cent. would mean an enormous saving in consumption. The consumption for domestic purposes—although only, as near as I can calculate, about 10 per cent. of the whole output—is the most wasteful, probably not much over 1 per cent. being actually used benefically.

If coal cannot be sold as cheaply as it has hitherto been, engineers in other branches will certainly try to find improved, and more economical ways of using it, and also of harnessing the sun, either direct, or through the medium of the wind, rivers, or tides; and by the time that the more cheaply worked coals are exhausted, probably considerable help may be obtained in this way. It is not, however, necessary to point out probable ways in which coal may be more economically used, or the possibilities of utilizing the sun's rays or other sources of power; but attention may be called to a few of the means which seem to be open to mining engineers, whereby greater safety and economy in production may be effected, so as to somewhat meet the prophesied competition of engineers in other branches, and also the competition of other countries.

At the present time, notwithstanding the greater depths from which coal is raised, the increased rate of wages which is now paid, and the greater expenses caused by Acts of Parliament passed of recent years, coal has, over an average of late years, been nearly as cheap as ever it was. To some extent this may have been caused by the cheapness of money, or the appreciation of gold, but the fact remains, that British mining engineers, will have to face quite as great, if not greater, difficulties in the future than in the past, in order to supply fuel cheaply, so as to meet the competition of foreign countries, particularly the United States of North America, and probably later, China and Japan, either in coal direct or, through the medium of manufactured steel or iron, which is the more probable form in which the competition is likely to declare itself. This will apply to a much greater extent when our more cheaply worked seams are exhausted. It must be borne in mind that any economies in con-

sumption will apply equally to foreign countries, so that it is to cheap fuel alone that our iron- and steel-industries will have to look.

A suggestion which has recently been brought to the front is that an export duty of as much as 5s. per ton should be placed on coal, one reason for its adoption being that coal fluctuates in price as much as this margin of 5s. per ton, and that therefore, 5s. would not, on the whole, handicap the trade. Coal certainly fluctuates over a series of years; unless there are, occasionally considerably enhanced prices, no money would ever be put into collieries. There are very few places where a colliery, to produce say 500,000 tons per annum, can, with certainty, be put down and equipped for less than £250,000. It may be taken that out of a decade, three to four years are practically profitless, two, say show moderate interest, while say the remaining four have to stand the ten years' interest, profit, risk and depreciation. The latter should be worked out over a period, say, of 25 years, which absorbs say £10,000 per annum, or say 1s. per ton on the four profitable years, while for the interest, profit and risk 12½ per cent. per annum is not an excessive amount. This in the four years would come to 2s. 6d. per ton; the extra cost from higher wages and increased cost of material during the four best years absorb the other 1s. 6d.: making a total of 5s. per ton in the four better years over the lowest. An export duty of 5s. would, however, be clapped on every year, even in those which needed a fillip of low prices to stir up the demand, so that remunerative prices might follow. It must be borne in mind that this cost of £250,000 for an output of 500,000 tons per annum is not an outside one, and may be taken as a moderate estimate. A higher sum will be necessary for the more expensive collieries. The high standing charges for such a colliery as I have described (exclusive of interest) necessitate its being worked at all times to the fullest extent, and this, when other trades are depressed: this brings down prices to a level at which the weakest cannot live: and at this level they are maintained usually for three or four years, that is, till those collieries have exhausted their resources and retired from the battle; then prices go up again, and capital is once more put into the business.

The coal-seams now being worked probably average 4½ feet in thickness, and the area of one seam (after allowing for waste in working) worked per annum will be at present nearly

40,000 acres, which, at an increase, cumulative, of 5 per cent. per annum, would in 1910, be over 50,000 acres, or a total in the 10 years of over 450,000 acres, or nearly 700 square miles. These are large figures, still as it has been computed by an eminent geologist that there are, within a depth of 4,000 feet, over 80,000,000,000 tons of workable seams remaining to be got (which is perhaps a slightly too favourable view of the quantity remaining), our present output would last, if no further increase takes place, some 350 years. But, assuming the increase to go on as it has latterly done, it will last less than 150 years. The cost of raising what is left half a century hence will, however, be somewhat greater than now, and in this respect I agree with Mr. Longden's views, and we have to thank him for calling attention to the matter.

Considerable discussion is taking place in the public press at the present time on this subject, so I will not commit myself any further, leaving it to a Royal Commission, which will probably be appointed to enquire into the matter. It is difficult for a mining engineer, only thoroughly conversant with one district, to be able to give an authoritative opinion upon a subject so wide as this.

With regard to the South Staffordshire district, with which I am more immediately connected, it has long been felt that it is merely a portion of the South Midland district, of which the Warwickshire and Shropshire, and possibly the Leicestershire and North Staffordshire coal-fields are all separate portions, but so far very little has been done to prove practically that this is so. A boring is being put down midway between Stafford and Wolverhampton, which has already proved that coal exists there, beyond what was formerly looked upon as the western boundary-fault of the Cannock Chase portion of the South Staffordshire coal-field.

On the eastern side, a bore-hole is being put down, some 2 or 3 miles east of what has hitherto been looked upon as the eastern boundary-fault. Reliable information is not to be had as to the result, but it is understood that mechanical difficulties have delayed the progress of boring.

The South Yorkshire and Derbyshire district has of late years moved its borders far to the east, with a further possibility, and even probability, of its renewed extension.

I am not sufficiently acquainted with other districts to form any opinion as to their undeveloped or improved resources, but

should what is being attempted with regard only to the two districts named prove to be successful, the apparent supply of coal will receive an enormous addition.

There is very little to be done, at the present moment, at many of the new large collieries which have been started during the last few years, in the way of cheapening the cost. All have been planned with due regard to the production of a large output at a minimum cost, but probably as the workings extend the costs increase somewhat. At the older collieries, it is very difficult to make changes which will recoup their cost in a reasonable time; still something may be done in many cases. The higher wages which are being paid at present will, however, necessitate changes, or make them more necessary than heretofore: many which have previously been suggested have been held in abeyance. One of the first things that occurs to me is secondary haulage, and this, I think, must come largely to the front. Of course, a great deal may be done by taking advantage of the gradients, and if stall-roads are laid out so that a horse can, in every case, bring out as many loaded tubs as he can take in empty ones, for distances up to say 1,500 or 2,000 feet, horse-haulage is as cheap as any mechanical means; and though this depends to a great extent on the tubs or trams, an average gradient of $\frac{1}{4}$ inch per yard will enable this to be done. The best secondary haulage seems to be an endless rope, going into three or four places, with one attendant; or possibly a main-and-tail rope may answer, knock-off joints with ropes going into each place being provided. The details may cause a little difficulty, but this is more a matter which each engineer can overcome for himself.

The capacity and make of the tubs themselves is a factor in the case, but this depends, to a great extent, upon the seams in which they are used. Although eminent mining engineers tell me that the larger the tubs or trams the more cheaply is the coal delivered at the pit-bottom, I am inclined to think that a middle course is preferable. Proper lubrication of the tub is also a great factor, and to this I think sufficient attention has not, in many cases, been given. For lubricating existing tubs it will be found that a cheap mineral engine-oil, costing about £10 per ton, gives very good results, at much less expense than anything else, but I cannot help thinking that tubs with roller-bearings will, when a more inexpensive design can be found, be adopted, especially where the working-places are a long distance from the shaft.

The cost of banking coal has been reduced to a minimum at many collieries, and if it is further reduced the tubs must be tipped direct from the cage on to the picking-belts, sufficient elevation being given to the headgear for the purpose (that is, to enable the coal to be tipped), due regard being had to the tipping being done in such a way that the breakage may be reduced to a minimum.

Mechanical coal-cutting is rapidly coming to the front, and the means of communicating power must, as far as I can see, be electricity. It has up to now been handicapped, to a great extent, by the electrical parts of the machine being too weak, resulting in too many breakdowns. As soon as this minor difficulty is overcome, much greater progress will be made in this respect. Of course compressed air is useful, but to my mind it is a much more expensive and inconvenient method of communicating power.

Electrically-driven drills will probably be found to do good work, more especially in stone-drifts, the advantages, however, only being apparent when long holes can be drilled, coupled with the use of high explosives; where short holes are used, the cost of moving the machine is more than the gain from its use.

More thought has, of late, been given to the mode in which explosives can be best utilized; and the enlarging of the shot-hole at the back, so as to make a chamber larger than the hole itself, will eventually enable rock-heads (or stone drifts) to be driven much more quickly than they have hitherto been. Where a sufficiency of explosive has been used the débris will be found to be moved further back, so that the drilling may proceed while the débris is being removed.

There is an important question in connection with electricity, and that is the best voltage at which to work, of course the higher the voltage the cheaper will be the cables for any given work, and the less will be percentage of loss. But there are dangers in connection with a high voltage which are absent with a lower one, and in pits there are so many chances of a man getting a shock that this is an item for consideration; 500 volts will not inconvenience a man in good health, while a shock from a 300 volts current might kill a man with a weak heart. Every one working in connection with an electric current should wear shoes with non-conducting soles.

As regards the best type of coal-cutting machine, a bar-cutter will answer in a seam with a strong roof, and much better in seams with bad roofs, where the tendency is for the seam to subside immediately after the holing. With a disc-cutter, a sprag can only be put in at the back of the disc, in the case of say a 5 feet disc, nearly 6 feet from the front, while in a bar-cutter a wedge may be driven in about a foot behind the cutter-bar. Some mining engineers prefer the disc-machine on account of the smaller cut taken out, but when this is done chiefly in the fire-clay, it is scarcely worth taking into account. Of course, my remarks under this heading are more immediately confined to long-wall holing: probably for pillar-and-stall, and other similar work, some other machine may be devised.

Steel girders have of late years been extensively used in the place of timber for underground workings, and will be much more extensively used in the future, though of course this depends on the seams themselves and the relative cost. With steel girders for heavy roofs, half the depth of the timber will, as a rule suffice, and this is of itself an economy, less roof having to be blown down, and the steel girder being more cheaply placed in position than a wooden one.

In tub-making, too, one of larger capacity may be made of steel than of wood, with the same outside dimensions, a plate $\frac{3}{16}$ inch thick taking the place of a board $1\frac{1}{4}$ inches thick, a saving of over 2 inches in both width and length. Steel, used underground, should, to save corrosion, be treated in all cases with an anti-corrosive paint.

Although for some six or seven years past, little, if any, profit has been made at any ordinary colliery, a great outcry is being raised about so-called "coal-rings." The fact is that, in order to continue their existence, the owners are making up something towards past losses. Owing to the want of profit in bad years, little money is put into the business, and the output does not increase, or rather the means to make an increased output, until sufficient profit has enabled this to be done. In a time like the present, capital is often put into collieries recklessly, and when the inevitable reaction occurs a great proportion is lost.

Another factor in the case is that with higher wages and more regular work, men turn out less coal than when wages are lower, my experience being that each man produces only 90 per cent.

of what he did two years ago, when trade was not so brisk. This decrease of itself causes a larger price per ton to be necessary to pay for the standing charges and interest, let alone the profit on the working.

The sympathy of the public always appears to be with the colliers. They deserve high wages, but scarcely from the point of view of many who advocate their cause; their employment is above the average, as regards health, or, rather, their death-rate is very low from natural causes, being actually lower than that of the butcher, baker, tailor or shoemaker, while that from accidents compares favourably with many callings which are popularly looked upon as safe ones, the annual death-rate from this cause having been reduced to a little over 1¼ per 1,000.

With the numerous difficulties against which he has to contend, the calling of a mining engineer is not, at all times, a happy one; he is much more restricted in his expenditure than his fellow-engineers in other branches of the profession, especially in bad years, yet he has to try to keep abreast of the times, and not only so, but to do everything with a very large margin of safety.

The education of a mining engineer is, at present, much more complete than formerly, while the advantages which a workman possesses are very great compared with what they were when I was a boy. On many occasions of recent years I have been present at the presentation of prizes to the students attending County Council lectures, and the books presented to them were such as, in my younger days, were not published. I cannot help thinking that if working colliers would take advantage of the opportunities which they have to learn, and afterwards make use of what they have learned, it would, while enabling them to get higher wages, be a factor towards making cheaper coal.

Although many British collieries are run on very economical lines, I think it would be desirable for mining engineers to visit the United States of North America, and learn what our competitors in that go-ahead country are doing. To some of us who are content to run on old lines, the revelation would be astounding. Of late years, the means of intercommunication between us has been much greater than thirty or forty years ago. However, much would be gained by all, if we took more advantage of the information at present open to us, by attending the meetings of mining institutions, and taking part in the discussions on the many subjects brought forward at those meetings.

When the North of England Institute of Mining and Mechanical Engineers, the pioneer of our mining institutions, was founded in 1852, the death-rate from explosions was 1½ per thousand, while the death-rate from falls was nearly 2 per thousand; now the death-rate from explosions is 1 in 3,000 but that from falls is still nearly 1 per thousand, or half what it then was, and that from surface-accidents nearly three-quarters of what it was in 1852. The accidents from falls of roof or sides have not decreased in proportion to those from explosions; this seems to show that the light, from which the greater immunity from explosions has arisen, is not much greater now than 50 years ago, and it seems to point to the fact that a better safety-lamp is needed, that is, one which will give more light. The best safety-lamp gives very little more than three-quarters of a candle-power, and if a lamp of moderate weight could be found which would give even 1 candle-power, I cannot help thinking that a lower death-rate from this cause, and also from the miscellaneous underground accidents, would follow. H. M. inspectors of mines are always most anxious for safety-lamps to be adopted, but until one which gives a better light, is produced I contend that there are mines in which a higher death-rate would follow from their adoption.

In conclusion, I hope that we may soon affiliate the South Wales Institution of Engineers and the other mining institutes of this country. They may be afraid of losing their individuality, but this, I can assure them, will not be the case, thus the South Staffordshire Institute, of which I am a member, is just as individual as it ever was, and this applies equally to the other federated institutes.

Mr. A. L. Steavenson (Durham), in proposing a vote of thanks to the President for his excellent address, said that as a much older man than the President, he thought he was right in saying that this was everything that an address should be. The question of the proposed duty on export coal was hardly a question which came within the objects of a mining institution. Mining engineers were told that selling prices were raised beyond what they ought to be, but this was matter with which they did not interfere. They knew that the present prices had occurred almost accidentally, and including them with the selling prices

obtained over a term of, say 20 to 25 years, the money invested in collieries did not yield a return of more than 5 per cent.: if colliery-owners never experienced high tides of prices they would soon cease to exist.

The President had referred to the reduction in the number of accidents during the time which had elapsed since the first Mining Institute was established at Newcastle-upon-Tyne in 1852. The number of mining accidents over which the mining engineer had any control had been materially reduced, more particularly those due to colliery-explosions and to falls of roof and side, in regard to which they had reached a point where the care of the workman himself was almost the only means of effecting any further improvement. And, though the improvement had not been so manifest as in other departments under the control of the mining engineer, they might hope that with the increased facilities for education which were afforded to the miner as well as to others, the workmen would become more sensible of their responsibilities. He had been surprised since the Workmen's Compensation Act came into force at the evidence which had been brought before mining engineers of the wilful carelessness of workmen, even when sedulously instructed in the measures requisite to secure their own safety.

Prof. Edward Hull (London) said that the President had alluded to several questions in which he took a great interest, and he did not know whether the President referred to himself when he said that some person had proposed to put a duty of 5s. per ton on exported coal. He had indeed made a similar proposal, but it was not exactly what he had proposed. He suggested, in the case of exports from this country to the Continent of Europe, that they were quite entitled to pay an export duty on coal; but he never for a moment suggested that this duty should be paid on the total export of coal from the British Isles. He considered that coal, being a natural product which once extracted could never be replaced, belonged in part to the nation, as well as to the coal proprietor or colliery-owner. If it was admitted that the whole nation had a lien or claim upon the coal, the nation was not being recouped for the coal which was gradually being extracted, and which could never be replaced. But if they could place a small export duty on coal sent to Continental ports, they would accu-

mulate a sinking fund which would tend to relieve the public of the increasingly heavy taxation, which was making life more onerous now than in the past.

Passing from this point, the President had referred to the trial-boring for coal in the country west of Birmingham. The mechanical breakdowns, to which the President had referred, had been most unfortunate, and but for this the Thick coal-seam would have been reached two years ago, whereas it had not yet been struck. The borehole had attained a depth of over 1,000 feet; he regretted to say that the Permian beds were of unusual thickness, and that was the reason they had not found even the Upper Coal-measures; but no doubt if the experiment succeeded in proving the Thick coal-seam east of the Staffordshire coal-field it would add largely to the coal-resources of that part of the country.* He had great pleasure in seconding the vote of thanks to the President for his excellent address.

The motion was very warmly agreed to.

DISCUSSION OF MR. G. K. RADFORD'S PAPER ON "MINING FOR GOLD IN THE AURIFEROUS GRAVELS OF CALIFORNIA, U.S.A."†

Capt. C. C. Longridge (London) wrote that greater interest, perhaps, might have been given to the paper if Mr. Radford had dealt, less with a general description of wellknown methods and appliances of alluvial mining, and more with their special application in California. The ingenuity of Californian mining-engineers was sure to have devised modifications and improvements suitable to local conditions, and for this reason, probably, little known to engineers in this country. Could the author give some information as to the reasons (1) for employing a wooden flume to lead the water through a long tunnel driven in granite; (2) for

* Since the meeting, Coal-measures have been entered by the borings at Smethwick.

† *Trans. Inst. M.E.*, 1899, vol xvii., page 452.

selecting a flume for this purpose in place of a pipe-line; and (3) for giving the flume a trapezoidal form, 2 feet wide at the bottom, and 6 feet wide at the water-line when 4 feet deep? The best form of trapezoidal section was usually considered to be that of a semi-hexagon, in which the bottom was equal to one of the sides. In the present case, the bottom measured 2 feet and the side about 2·83 feet.

For steel hydraulic pipes, he (Capt. Longridge) believed that from 27 to 32 tons of tensile strain is the outside limit for rivetted pipes. As regards the rivetting of steel hydraulic pipes, there was considerable variation in practice, and apparently no fixed rule for determining the size and pitch of rivets. His recent work on *Hydraulic Mining* contained a rough table of rivetting details, which wide experience had proved suitable for plates under $\frac{3}{4}$ inch thick. For heavy pressures, longitudinal seams should always be double-rivetted, while circular seams were single-rivetted. Among the pipe-line fittings, was it an omission that no mention was made of expansion-joints?

The funnel-shaped inlet of the pipe-line, mentioned by the writer, was obviously intended to diminish the "entry-head" loss. The water entering the pipe with a gradually increasing speed, and therefore needing far less force than would be required to impart suddenly a high velocity. The bell-outlet was presumably intended to lessen the impact of the discharge. Mr. Radford's description of "dry-mining" by a "clam-shell" dredge, suggested a condition of things likely to give place to more modern and efficient machines.

On the points raised for discussion, he (Capt. Longridge) thought little could be said. As regards variation in the pipe-diameters, this was not customary in this country. But for easy and cheaper shipment purposes, it was often employed for water-schemes abroad. Naturally the largest diameter and the least thickness was placed near the source of supply. There was no rule governing the variations in diameter.

The cost of laying a pipe-line depended almost entirely on the country and on the nature of the ground traversed. The only fairly constant item, subject, however, to market fluctuation, was the cost of the pipe itself. Freight and labour varied in every part of the world, and another equally variable factor was the number of obstacles to be overcome in laying a fairly straight and properly

graded line. Figures as to costs might, the writer thinks, be very misleading, unless accompanied by very minute details of each case.

Mr. G. K. RADFORD wrote that the formula at the end of his paper,* should read T = P.R/S, in which T is the thickness of the pipe; R, the radius of the pipe; P, the unit of pressure; and S, the unit of strength.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1899.

The Report of Prof. H. LOUIS, the delegate representing the Institution, was read as follows:—

THE DURHAM COLLEGE OF SCIENCE,
NEWCASTLE-UPON-TYNE, MARCH 20th, 1900.

TO THE PRESIDENT AND COUNCIL OF THE INSTITUTION OF MINING ENGINEERS.

GENTLEMEN,

As your delegate at the 1899 meeting of the British Association for the Advancement of Science, I have in the first place to express my regret that I was unable to be present at the meeting of delegates, and secondly to submit to you a brief summary of the proceedings. I wish to take this opportunity of pointing out the extreme inconvenience caused by the overlapping of the meetings of the British Association for the Advancement of Science and of The Institution of Mining Engineers; the date of the former being always fixed long in advance, I would suggest that it would be easy to arrange the date of our own meeting so as to keep clear of the former.

The proceedings of the Conference of Delegates of corresponding societies contained little that could possibly interest the members of The Institution of Mining Engineers. The first meeting was taken up by an address from the Chairman on the Living Subterranean Fauna of Great Britain and Ireland, in which an incidental reference was made to a copepod from a Northumbrian coal-mine, described by Dr. G. S. Brady. Obviously there is here a field of research for such mining engineers as may be fortunate enough to have the leisure for these studies.

At the second meeting of the Delegates, a discussion took place as to the best way of improving the meetings of the Conference and of making them more useful than at present, and suggestions were made as to the subjects in which the co-operation of corresponding societies might be useful. The only points that might in any way interest The Institution of Mining Engineers were a request from Section C for photographs of geological interest and from Section D for the study of subterranean fauna.

* *Trans. Inst. M.E.*, 1899, vol. xvii., page 480, line 15.

At the meetings of the British Association for the Advancement of Science, the following papers were read on subjects of interest to mining engineers:—

"The Relation between the Dover and Franco-Belgian Coal-basins." By Mr. Robert Etheridge.

"The South-Eastern Coal-field." By Prof. W. Boyd Dawkins.

"Recent Work among the Upper Carboniferous Rocks of North Staffordshire and its bearing on Concealed Coal-fields." By Mr. Walcot Gibson.

I am, Gentlemen.

Yours obediently,

HENRY LOUIS.

The PRESIDENT (Mr. H. C. Peake) moved that a hearty vote of thanks be accorded to Prof. Louis for his services as delegate and for his report.

Mr. M. WALTON BROWN seconded the motion, which was cordially adopted.

The following paper by Mr. H. FOSTER BAIN on "An American Longwall Mining Machine" was read:—

AN AMERICAN LONGWALL MINING MACHINE.

By H. FOSTER BAIN, Assistant State Geologist of Iowa, U.S.A.

In a former paper,* the author described the work of coal-cutting by machines in Iowa mines. At that time, the longwall machine developed by Messrs. Lee Brothers, of the Peerless Coal Company, Centerville, Iowa, was mentioned. As that machine has proved successful in the two years and more in which the perfected type has been in use, it may be of interest to describe it.

In America, and particularly in Iowa, but little coal is mined by longwall methods. This is mainly due to the character of the Coal-measures, favouring as they do the various forms of room-and-pillar work, but in part it has seemed to the author to be due to lack of familiarity with longwall methods. However that may be, the machines so far developed are used primarily for room-and-pillar work. It is probable that neither the chain-breast nor the pick-machine is being, or can be, used to any great advantage in longwall work. The reason for this is obvious. The great weight thrown on the face of the coal in all longwall work makes it impossible to maintain there an open space such as is necessary for any of the machines of the types commonly used. The chain-breast or cutter-bar machine requires in practice approximately 10 to 12 feet of open space, and the pick-machine, while not requiring usually so much, still needs more room than can be obtained under any but the most exceptionally favourable circumstances.

Of the two general plans for working coal (longwall and room-and-pillar), the former is, where the conditions will allow its adoption, incomparably the most economical. It does away almost entirely with the necessity for leaving coal in the ground, and in well-planned and well-executed longwall work, practically all the coal is hoisted. There are of course many mines where nothing but room-and-pillar work is possible, but the number of mines

* *Trans. Inst. M.E.*, 1897, vol. xiii., page 478.

working on a longwall system is in some regions really considerable. So far the longwall mines have been shut out from the benefits, direct and indirect, of the introduction of coal-cutting machines. It is true that longwall machines of various types have been made and used for some years, and there are such machines now on the market, but even the manufacturers of the latter are modest in their claims, and in general the benefits derived from their use have been very slight.

The earliest longwall machine seems to have been designed in Great Britain, and it was made to imitate very closely the action of the miner as he lies on his side and swings his pick under the coal. Later, horizontal revolving discs, set with teeth, were introduced, and still more recently a projecting arm, carrying a chain armed with teeth, and similar in action to the chain-breast machine, has been tried.

All these earlier machines were heavy, bulky, uncertain in their action, exacting in their requirements as to track, and none were self-propelling. They required to be anchored ahead and moved forward by reeling up a rope or chain attached to the machines. This at once introduced the difficulty that they could only cut in a straight line, and the very nature of longwall work requires a jagged or circular face. Some of the best of the machines now in use need to be jacked into position, and held there by heavy set-screws. No great economy can be expected from their use under any but exceptionally favourable circumstances.

It has been the author's good fortune to watch the development, in its final stages at least, of a longwall machine which is very simple in operation, remarkably successful where now used, and applicable, he thinks, to a wide range of longwall work. The development of the machine, by the way, is quite as interesting as the work which it does. It grew out of the daily needs of a small local mine; it is the result of a half-dozen years of experiment and effort, and was built in a local shop, under the direction of a man who had no previous training in either coal-cutting machines or electricity, but who knew very definitely what he wished to accomplish, and paid liberally for advice when he required it. It is interesting to note that in its embryonic history it repeated that of the earlier machines. The first attempt at undercutting, for example, was by means of an horizontal circular saw, much like that used on the Mitchell machine. This was soon discarded, and a project-

ing arm, around which ran a chain set with picks, was tried: this was attacking the coal as does the chain-breast machine. It was found, however, that in travelling over the uneven floor along the face, the machine necessarily moved up and down, and this interfered with the chain, which could only cut out effectively when the machine was running along a true horizontal plane. The irregular condition of the mine-floor led to the development of a spiral cutter-bar, and this has been shown to meet the conditions admirably.

The machine consists essentially of a self-propelling motor, running on an horizontal track parallel to the face, and driving a projecting cutter-bar, moving in an horizontal plane under the coal, set spirally with teeth and revolving rapidly. The different parts of the machine are shown in Figs. 1 and 2. In outside dimensions, it is 24 inches wide, 52 inches long, and 27 inches high. The type in use undercuts 30 inches, and weighs 3,200 pounds. The motive power is electricity, though compressed air or other power is equally applicable. The motors used are of the ordinary type used in street-car work, and rated at 15 horsepower. In ordinary work about 8 horsepower are used, and in hard cutting about one-fourth more is occasionally called for. The voltage used is 220. In the first mine equipped, it was found that when working 1,800 feet from the engine-room there was a loss in transmission of approximately 10 per cent.: this was, however, largely due to defective insulation. In the mines more recently equipped, the working losses are brought within 5 per cent. No. 0 covered wire is used for underground connections, but uncovered wires are used aboveground to connect the central power-station with the mines. The figures given of power used include loss in transmission, and were obtained from the current-indicator in the engine-room.

The track upon which the machine runs consists of two rails, one notched and placed next to the face, and the other plain, parallel to the first, and set about 18 inches away. These rails are made of common $1\frac{1}{2}$ inches angle-iron. In the case of the plain rail, two bars are rivetted together, so as to give an inverted T cross-section with a 3 inches base. The outer rail is made by using rivets $\frac{1}{2}$ inch in diameter, upon which shoulders are cut, so as to hold the two angle-bars about $1\frac{1}{8}$ inches apart. These rivets

FIG. 1.—THE LEE LONGWALL MINING MACHINE, SHOWING THE CUTTER-BAR IN POSITION FOR ADVANCE-WORK.

FIG. 2.—THE LEE LONGWALL MINING MACHINE, WITH CUTTER-BAR IN POSITION FOR ATTACKING THE FACE.

are set at intervals of 1½ inches, and the effect is that of a flat-bottomed rack-bar. These rails are made in suitable lengths for easy handling, and two of each are required. The rack-bar is laid flat on the ground, with sprags braced against the coal, and a crow-bar brace against the roof at the rear. The outer rail is unbraced, and there are no cross-pieces connecting the rails. When the machine is running, the extra set of rails is set ahead of it, and when the machine comes upon them the sprags of the released rail are knocked loose, and the rail is passed forward alongside the machine and relaid ahead. The operation of track-laying is carried on by the two men who operate the machine, without stopping the latter or in any way interfering with its work. The machine propels itself by means of a teethed-wheel meshing with the rack-bar.

At first glance, it would seem that it would be necessary to lay the track very carefully and to brace it thoroughly. In fact, it is customary to use jacks in the case of other machines, but in practical work the Lee machine requires that only the slightest attention be paid to the track. Only when the bottom is wet and slippery is it necessary to use any care in placing even the few braces mentioned, and in the interval of changing the crowbar brace from the released to the engaged rail the machine seems to work quite as well as ever. The braces are more matters of precaution than otherwise. The outer or idler wheels are swung on pivots, and hence accommodate themselves readily to horizontal irregularities in the track. Vertical irregularities are compensated by means of a device for raising or lowering each wheel separately, shown in the small handle projecting above the upper right-hand wheel in Fig. 1. By means of this device, it is possible to make the machine cut up or down from the horizontal plane. This arrangement compensates for irregularities in the floor, and allows the cutting over or under any obstruction. It is also useful, as it makes it possible to use more or less dirt according to the needs in packing.

It is obvious that this method of propulsion has a distinct advantage over the older plan of dragging the machine forward by winding in an anchored wire or chain, in that horizontal irregularities of face, often essential to the success of longwall work, are compensated. The rate of forward movement can be regulated. In work at the Mystic mine, the feed is 12 inches per minute, but

this is sometimes exceeded, and in one piece of measured work, 20 feet were cut in 18 minutes.

The essential and novel feature of the machine is the form of cutter-bar, which is (so far as known) wholly new. This bar is $2\frac{1}{4}$ inches in diameter at the machine, and $1\frac{1}{2}$ inches at its outer end. It was first made, as shown in Fig. 2, detachable, and was screwed in a revolving shaft permanently fixed in the machine. The shaft and bar are now made in one piece, and so arranged as to be very readily slipped out and replaced when the teeth are dull. Around this bar is fastened a spiral band of steel with 42 projecting teeth, much resembling in outline the teeth of a cross-saw. This band is made of the best tool-steel. The teeth are cut and set so that they do not quite cover each other, and it is estimated that their work is 1 part cutting and 3 parts breaking. The cutter-bars are used for undercutting about 100 linear feet and then reground. The latter operation takes about 5 to 10 minutes. Each set of teeth is good for about 10 weeks' work, after which the three rivets which fasten the spiral band to the bar proper are knocked out and a new spiral is slipped on. It is estimated that the cost of the teeth is about $\frac{3}{8}$d. ($\frac{3}{4}$ cent) per ton of coal won.

An important feature of the cutter-bar is the spiral arrangement of the teeth, as the effect is that of a screw-conveyor in clearing out the undercut. Another important feature is the ability to turn the bar on a vertical pivot by means of a hand-wheel shown at the lower left-hand corner of Fig. 2. By this means, the bar can be thrown to the rear for the purpose of changing from a dull to a sharp cutter without disturbing the position of the machine at the face. This change takes up about 5 minutes. By means of this device, the machine is made to cut its way into the coal so that no pick-work is necessary in starting it: this is an indispensable feature of a successful machine.

As shown in Figs. 1 and 2, there is an arrangement for fitting truck-wheels to the machine for conveying it from point to point in the mine, and the delicate parts of the machinery are protected from dirt.

At present, twelve machines are in operation, and four are building for the next winter's work. They are all used in the mines of the Electric Coal Company, of which the inventors are the chief owners. The coal worked is the Mystic bed, described in the writer's former paper.

The machine cuts, indifferently, in coal or fire-clay. It cannot,

of course, be worked to advantage in any layer heavily charged with pyrites, though it handles readily somewhat large spheroids of that material, and on the whole, so far as the author's observations went, it is as successful in this particular as the chain-breast machine. The fact that the cutter-bar may be tipped gives it some facility in dodging such material. For work in harder material, it would probably be necessary to adapt the machine by changing the relative weight of its parts or increasing the whole. The present smooth working in the Mystic coal-seam is the result of many experiments along this line, and this perfect adjustment of weight is also the secret of its success in self-propulsion.

In ordinary everyday work, the output is 40 to 60 tons of coal, 600 to 650 square feet of undercut, for each machine, in a working shift of 8 hours, with two men to each machine and 10 to 12 followers loading coal, building pack-walls, etc. In March, 1897, on a record run, 1,362 square feet were undercut in 9 hours and 50 minutes, with a yield of 109 tons of weighed coal. The total cost for labour in undercutting is, at the present rate, 5½d. (11 cents) per ton. Records of repairs and breakage for twelve months showed a cost of $\frac{3}{16}$d. to ¼d. ($\frac{3}{8}$ to ½ cent) per ton. In general, as compared with hand-work in the same field, and even in the same mines, there is a saving of about 20 per cent. in the cost of machine-mined coal. It should be remembered, when considering the output per machine, and hence the cost per ton, that the Mystic coal is a thin bed and yields at best only about 2½ feet of coal. As it is, the whole cost of running the mine can be paid and profits won at the price paid to pick-miners alone for hand-work.

There is a large amount of this coal in the Iowa field, nearly 1,500 square miles, much of which is yet undeveloped, and there are other beds in the region to which the machine seems applicable. In any wide application of it changes would of course be necessary to meet local conditions, but the essential features may be fairly claimed to have proved correct in theory and feasible in practice.

The writer is indebted to Messrs. David A. and Thos. E. Lee, of Centerville, for permission to publish this description of their invention.

Mr. Walter T. Goolden (London) said that the only difference he could see between the machine described in Mr. Bain's paper and those which had been used in this country for the past

10 years was the special method of fixing the cutters on the bar, which might be an improvement on the usual method. Instead of being fixed into holes bored into the cutter-bar, they appeared to be fastened on in some way from the outside. He noticed that a 15 horsepower motor was used, which was about half of the power that would be required for the seams in this country; and that the machine only undercut about 30 inches, while in this country machines were undercutting to depths of 4 and 5 feet.

Mr. S. F. Walker (London) said that the President, in his address, stated that electrical coal-cutting machines so far had not been so successful as might have been the case, because they were not sufficiently strongly constructed and were not provided with sufficient motive power. This was certainly one cause, if not the entire secret, of the want of success of electrical coal-cutting machines in this country. The seams in the United States appeared to be more easily worked by coal-cutting machines, than our British seams; he read a paper some time ago in which 12 horsepower was given as the average power applied to coal-cutting machines used in a large American mine. His own view was that 30 horsepower should, at least, be provided, and as much more as was possible, as they were not obliged to use it all. The self-governing of an electrical motor enabled them to use from 1 horsepower upwards as required, and therefore there was no loss beyond the original outlay from having a powerful motor; but, on the other hand, if they provided a motor of insufficient power, two troubles were found: the machine could not get through its work, and the motor was constantly being burnt up. A small motor was only made to take a current of a certain strength, and if it stopped or got more work than it could perform there was no path for the current and the motor burned up, causing endless trouble. It would be of great service, if the author could give a little more information as to what was the practice in America, so that it might be compared with what was being done in this country.

The Rev. G. M. Capell (Passenham) said that he could fully corroborate the point which Mr. Walker had mentioned. If the motor was made slightly smaller than was necessary it heated, and power was dissipated in heat instead of being applied to the axle. He had made it a rule to apply considerably more power in the motor than was actually required in the work to be done.

Mr. C. C. Leach (Seghill) asked what was the margin that Mr. Capell allowed.

Mr. G. M. Capell said that at the present time he had only gone lightly into the matter, but he had arrived at the conclusion that an allowance of 25 per cent. should be provided.

Mr. T. E. Forster (Newcastle-upon-Tyne) said that such a margin would be found rather small for coal-cutting machines. It was not a bad rule to double the power required.

Mr. S. F. Walker said that his rule was to calculate the power which was likely to be required, and to multiply it by 10.

The President (Mr. H. C. Peake) said that it was desirable to have surplus power for electrical work, especially underground. As soon as the armatures and magnets got heated, they acted and reacted, and they soon were burned out. He thought that if a machine of double power was used, they would probably obtain more than double the work from it. He imagined that the machine described in Mr. Bain's paper took so little power in proportion to those used in this country, because the cutter-bar was shorter and smaller in diameter, and made a much smaller cut. He had experienced difficulties with the cutter-bars of coal-cutting machines; at first, they would only cut about ½ mile of the face and then small cracks kept starting in the holes into which the cutters were driven, and with the constant jarring of the machine these speedily extended. He had got over the difficulty by making the bars square, and he did not think that they had broken one square bar. He did not know any rule, but suggested that probably the power taken would be in proportion of the square of the diameter of the cutter-bar, and therefore, if the cutter-bar of the Lee machine was half the diameter of a British machine, probably the current required was not much more than one quarter. The Lee machine seemed to involve a novelty as regards the method of propelling by means of a teethed wheel; coal-cutting machines had generally been propelled by means of a thin wire-rope coiled on a drum. He had pleasure in moving a vote of thanks to the writer of the paper.

Mr. M. Walton Brown seconded the motion, which was cordially adopted.

Mr. Henry Davey read the following paper on "Compound Cornish Pumping-engines":—

COMPOUND CORNISH PUMPING-ENGINES.

By HENRY DAVEY.

The idea of compounding the Cornish pumping-engine originated by Hornblower in 1781, was taken up in Cornwall by Trevithick, Gribble, Sims, Woolf, and others, and many compound pumping-engines were erected in the county. But although some of the engines did good duty, no better results were obtained than with the best single-cylinder engines. Most of the compound engines were not properly designed for the best effect, but as the boiler-pressure was only about 40 pounds per square inch, the compound engine had no *raison d'être.*

In 1824, Woolf erected a compound engine at Wheal Alfred mine, intended to be supplied with steam from cast-iron boilers at a pressure of 100 pounds per square inch, but owing to the failure of the boilers, the engine was removed.

At the present time, steam-boilers are so constructed that steam-pressures varying from 150 to 200 pounds per square inch may be safely employed; but the single-cylinder Cornish engine cannot be made to utilize the expansive force of such high-pressure steam. To properly utilize high-pressure steam, resort must be had to the compound principle.

In order that we may be able to estimate the economy to be derived from the use of high-pressure steam as compared with that of a lower pressure, it is desirable to have a standard of comparison. One steam-engine may be shown to be better than another by its using less saturated steam per indicated horse-power per hour, or by its producing a greater number of work-units per heat-units expended. The thermal efficiency of the engine may be thus expressed:—The thermal efficiency is equal to the heat utilized divided by the heat supplied. The efficiency of engines thus expressed enables one to compare their relative economy: but as higher pressures possess greater possibilities of economy, we require a standard of comparison which shall be applicable to the conditions under which the engine works, where-

by we may be able to judge how far it has advanced towards perfection. The true standard is the ideally perfect steam-engine: an engine taking steam at the higher pressure and expanding it adiabatically to the lower or exhaust pressure without loss. The formula for such an engine was determined by Dr. Rankine.

The practical lower temperature for condensing engines is about 100 degrees Fahr., which may be taken as a good working standard. The writer will not trouble the members with Dr. Rankine's formula, but he has constructed an empirical one which is sufficiently near for all practical purposes, and of extreme simplicity. If we take 100 degrees Fahr. as the lower temperature, then (approximately) the pounds of steam required per indicated horsepower per hour in the theoretically perfect engine would be:— $\frac{2{,}540}{\text{Higher Temperature} - 40^\circ}$, or $\frac{2{,}540}{T - 40}$. This formula should only be used for absolute pressures between 30 and 200 pounds per square inch, but within these limits the errors are small, as will be seen from Table I.

TABLE I.

Condensing Engines: Exhaust Temperature, 100° Fahr.				Non-condensing Engines: Exhaust Temperature, 212° Fahr.			
T.	Boiler Pressure absolute.	Steam used per Indicated Horsepower per Hour.		T.	Boiler Pressure absolute.	Steam used per Indicated Horsepower per Hour.	
		Dr. Rankine's Formula.	$\frac{2{,}540}{T-40}$			Dr. Rankine's Formula.	$\frac{2{,}540}{T-192}$
Degs. Fahr.	Pounds per Sq. Inch	Pounds.	Pounds.	Degs. Fahr.	Pounds per Sq. Inch.	Pounds.	Pounds.
228	20	13·34	13·51	...	...	...	...
267	40	10·82	11·19	...	...	...	...
292	60	9·80	10·08	292	60	25·10	25·40
312	80	9·13	9·34	312	80	20·69	21·16
328	100	8·68	8·82	328	100	18·25	18·68
341	120	8·36	8·43	341	120	16·72	17·05
353	140	8·09	8·11	353	140	15 55	15·78
363	160	7·88	7·86	363	160	14·72	14·85
373	180	7·69	7·63	373	180	13·99	14·03
382	200	7·53	7·43	382	200	13·40	13·37

The empirical formula for non-condensing engines is $\frac{2{,}540}{T-192}$.

It will be seen from Table I. that the theoretically perfect engine using steam at a pressure of 40 pounds per square inch would require about 11 pounds of steam per indicated horsepower per hour; but if the pressure be increased to 200 pounds, then

only 7·5 pounds of steam would be required. Assuming then that we have two engines each capable of working with a steam-efficiency of 60 per cent., but one having a steam-pressure of 40 pounds and the other a steam-pressure of 200 pounds per square inch, then the steam-consumption in the former case would be 18 pounds per indicated horsepower per hour and in the latter case 12·5 pounds per indicated horsepower per hour. Table I. then enables us to see at a glance the economy that might be derived by using steam of a higher pressure.

The distribution of steam in the Cornish engine is one peculiarly adapted to the working of pumps, by the wellknown system of pump-rods. The weight of the pump-rods and attachments performs the function of a fly-wheel, thereby admitting of expansive working in the cylinder. But it has been found that the extreme practical limit of expansion in a single-cylinder Cornish engine is 4 to 1; that is to say if the steam is taken into the cylinder at 40 pounds absolute pressure, it may be expanded down to 10 pounds pressure, or say 5 pounds below the atmosphere. This is the limit of expansive working in the single-cylinder Cornish engine, and therefore it is of little use to employ a boiler-pressure higher than 40 pounds.

The theoretical reason for the limit has been often explained and is well understood.

Referring to Fig. 1 (Plate VI.), the shaded area above the line, AB, represents the energy absorbed in putting the rods in motion; while the shaded portion below the line represents the energy recovered in bringing the rods to rest again. To get such an effect as that shown in Fig. 2 (Plate VI.), the rods must be very heavy, or their velocity very great. To reduce the weight or the velocity would be to reduce the expansion illustrated in Fig. 1 (Plate VI.).

By the use of a second cylinder greatly increased expansion may be employed, and therefore greatly increased pressure, because the resultant effect of expanding first in one cylinder and then in the other is to reduce the difference of the effective steam-pressures between the beginning and the end of the stroke.

Referring to Fig. 3 (Plate VI.), let steam be cut off at about half-stroke in the small cylinder. During the equilibrium-stroke, the pressure is indicated along the line G, and cushioning takes place at X; at the same time the equilibrium steam-pressure

for the large cylinder is indicated along the line H, and the cushioning at Y, the condenser-pressure being indicated at K. The work done in both cylinders may be taken to be the full area of the diagrams, minus the small losses caused by the passage of the steam during the equilibrium-strokes, and between the two cylinders. For the sake of illustration, the diagrams may be taken to represent the total work; the area ABCDA, that done in the small cylinder, and the area FADEF, that done in the large cylinder. In order to refer all to the low-pressure cylinder, the ordinates of the upper figure must be divided by the ratio of the capacities of the two cylinders. In this case the capacities are 4·6 to 1.

In Fig. 4 (Plate VI.), the work done in the small cylinder is represented by the area BEFCB, and that in the large cylinder by ABCDA: the total effect referred to the large cylinder being AEFDA.

In Fig. 5 (Plate VI.), the line AB is drawn through the point of mean pressure, so that the rectangle ABCDA represents the total work done by the engine on the steam stroke, and the area AXYA the work represented by the *vis viva* acquired by the load, during the former part of the stroke and given out again during the latter part. On comparing this with the single Cornish-engine diagram Fig. 2, it will be seen that the compound engine with more than three times the steam-pressure, greatly increased expansion, and greater mean pressure, does not require so heavy a mass or so great a velocity during the steam-stroke for its effective working. It will also be seen that the strains on the engine are reduced. The initial strain is only 1·3 times the mean, whilst in the ordinary Cornish engine it is twice the mean. It will also be observed that the work done by the small piston is applied to the pump-end of the beam, so that less than one-half of the work of the engine comes on the beam-centre.

Duty of Cornish Pumping-engines.—The maximum economy is obtained by using the greatest boiler-pressure and the highest rate of expansion which the principle of the engine would permit, the limits being about 40 pounds boiler-pressure and 4 to 5 expansions. The average duty was about 50,000,000 foot-pounds on 112 pounds of coal, or in the best examples from 60,000,000 to 70,000,000 foot-pounds. In some cases 90,000,000 foot-pounds

have been obtained on 112 pounds of coal with a high evaporation; and results as high as 130,000,000 have been claimed on 94 pounds of coal, but such a high result is impossible. One horsepower per hour is equal to 1,980,000 foot-pounds, or say, in round numbers, 2,000,000 foot-pounds, and a duty of 130,000,000 foot-pounds is equivalent to 65 horsepower-hours; and 94 pounds of coal divided by 65 horsepower-hours is equal to 1·45 pounds of coal per indicated horsepower per hour.

With an evaporation of 10 pounds of water per pound of coal, the feed-water per pump-horsepower per hour would then be 14·2 pounds, and assuming a mechanical efficiency of 80 per cent., we have 11·36 pounds as the consumption of steam per indicated horsepower per hour. Taking the initial pressure as 40 pounds, we have as the efficiency-ratio (10·7 ÷ 11·36 =) 90 per cent. The best efficiency obtained with Cornish engines is about 60 per cent., and generally much lower.

Expressed in weight of steam, the average engine used from 26 to 30 pounds of steam per indicated horsepower per hour. A better result has been obtained on short trials, and a consumption as low as 18 to 20 pounds per indicated horsepower per hour has been recorded, but no further economy could be obtained with a single cylinder, nor could better results be secured by a compound engine with the same boiler-pressure. It is only quite recently that high-pressure steam has been applied to the Cornish engine.

By the use of a second cylinder, the strains on the engine and pump-rods are reduced, and a greater range of expansion is secured, thus adapting the engine to the use of high-pressure steam.

The author having recently to design a pumping-engine for the Basset mines, Cornwall, adopted the Cornish system of steam-distribution, and by employing two cylinders, he succeeded in using steam at a boiler-pressure of 150 pounds per square inch.

Fig. 7 (Plate VI.) is an elevation of the engine, in which A is the high- and B the low-pressure cylinder, both cylinders having the Cornish cycle of steam-distribution. The pistons of both cylinders are connected to a steel rocking-beam, C, one piston making the up-stroke whilst the other makes the down-stroke. The beam extends beyond the small cylinder over the shaft, and gives motion to the pump-rod. The inner end of the beam is made of box-section to receive the balance-weights. The cylinders are 40 and

80 inches in diameter and have 9 and 10 feet strokes respectively. The stroke of the pumps is 13 feet; the pump-plungers are 18 inches in diameter and the present pit-work extends to a total depth of 1,000 feet. At 8 strokes per minute the actual horsepower is 360. The engine has only been at work for a few months, and no trials have yet been made as to the consumption of steam, but the consumption of coal has been found from week to week to be one half that consumed by a good Cornish pumping-engine on the same mine doing similar work. Practically the duty is over 90,000,000 foot-pounds on the coal used. The evaporation is probably 7 pounds of water per pound of coal. The duty therefore on an evaporation of 10 pounds of water per pound of coal would be 110,000,000 foot-pounds.

It is not likely that this engine will give as high an efficiency-ratio as 60 per cent., but an efficiency-ratio of 50 per cent. with 120 pounds of steam-pressure would make the feed-water per indicated horsepower per hour equal to 16 pounds. An efficiency-ratio of 60 per cent. would reduce the feed-water to 13·3 pounds. In this engine, the cylinder and nozzles of an old Cornish engine were used as a low-pressure cylinder. An entirely new engine might be expected to give a much better result. The water-load on the engine (all referred to the large cylinder) is equal to 30 pounds per square inch. This is double the proper load of the old Cornish engine.

An 80 inches engine, on this system, may be made double the power of the ordinary Cornish engine, and as the first cost of the engine is not greatly in excess of that of the single-cylinder engine, the cost of the new engine per horsepower is lower.

It will be seen that by placing the high-pressure cylinder, A, on the pumping side of the beam-centre instead of by the side of the low-pressure cylinder, B, the strain on the beam and the weight on the centre are greatly reduced (Fig. 7).

Fig. 8 (Plate VI.) shows two compound Cornish engines, each of 400 actual horsepower, applied to a circular pit, 17 feet in diameter, leaving ample room for winding-cages, etc. The engines might be applied in duplicate to one common rising main: the valve-gears of the two engines being so applied that when working together, one engine makes an up-stroke whilst the other makes the down-stroke. The engines could, however, be worked singly, one being kept in reserve.

Figs. 9 to 13 (Plate VII.) illustrate a compound Cornish engine

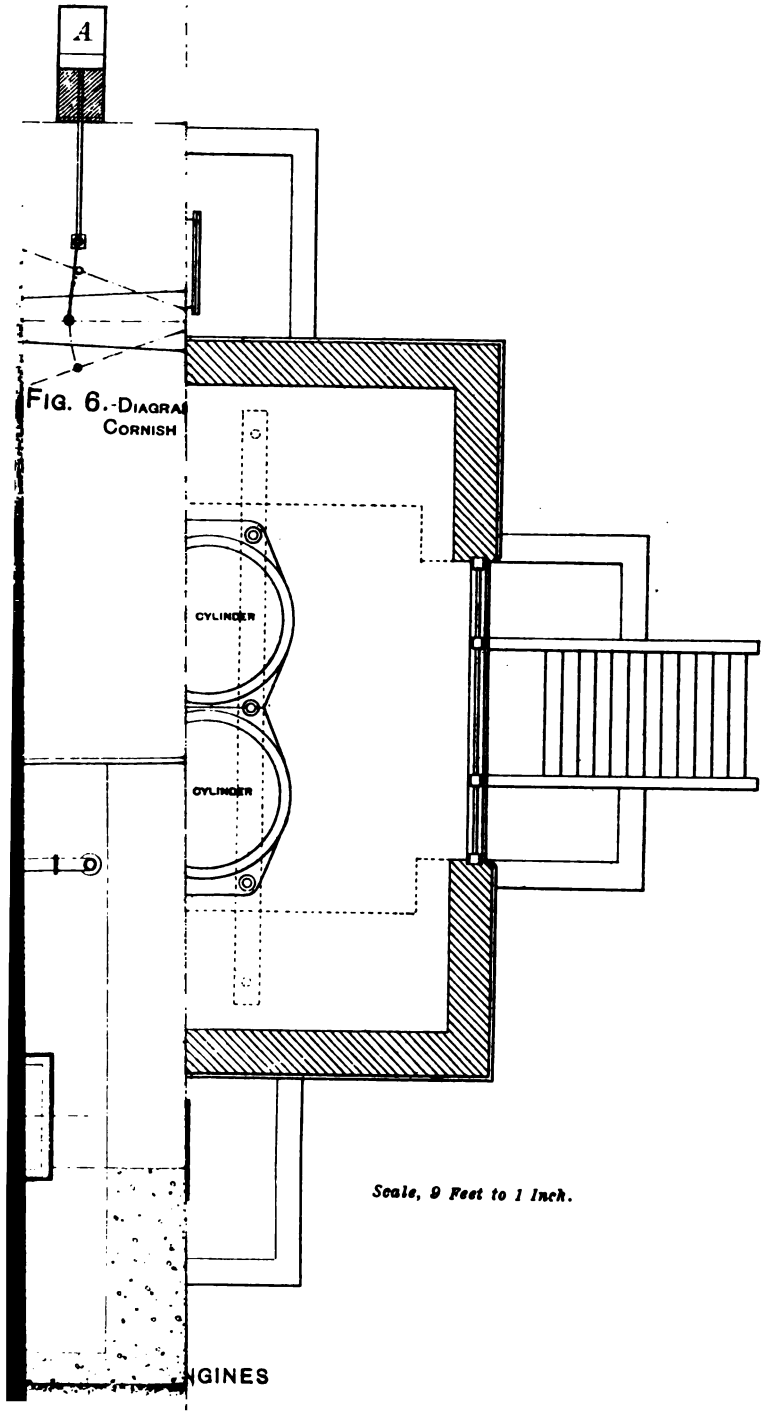
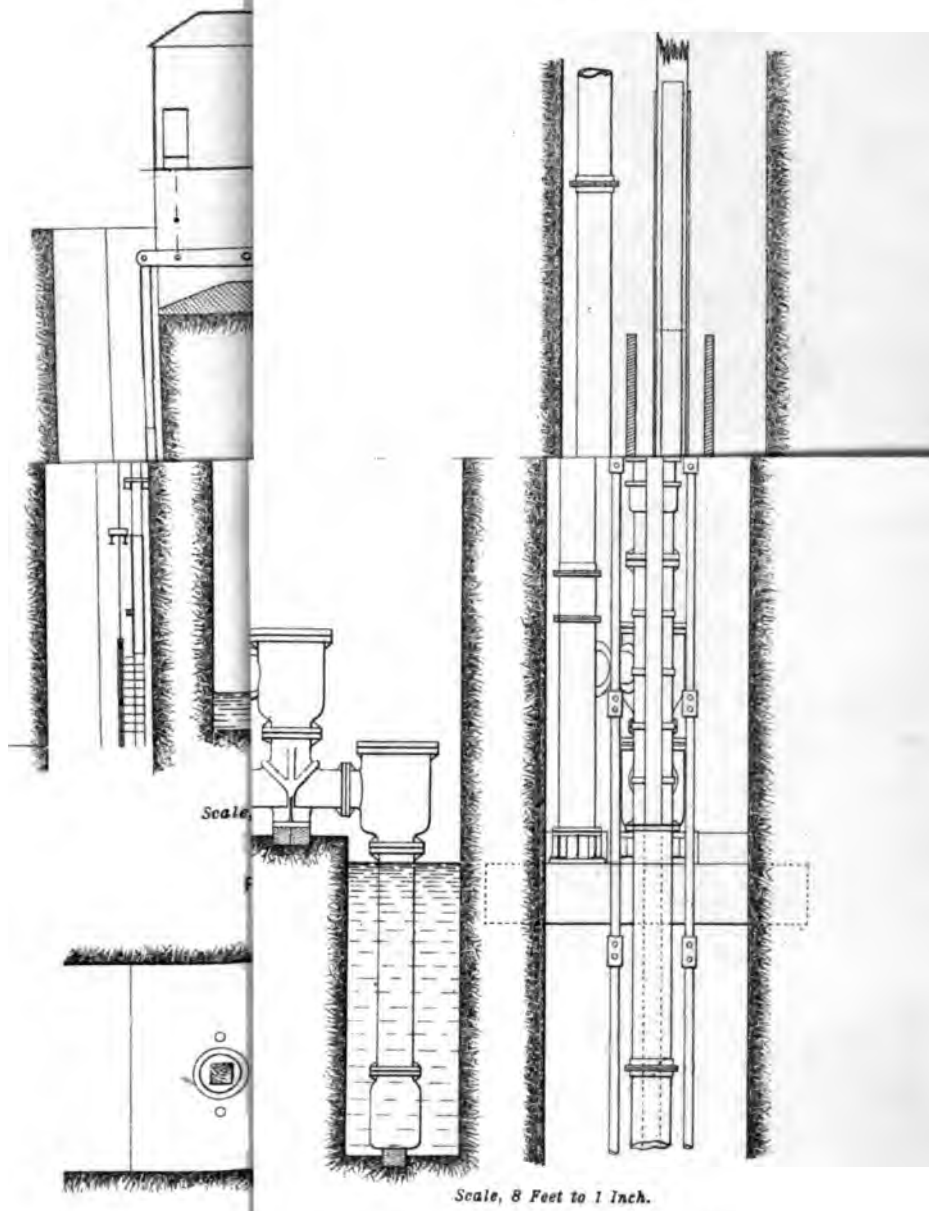


FIG. 6.-DIAGRA
CORNISH

Fig. 9.—Longitudi...

Fig. 12.—Cross Section.



Scale, 8 Feet to 1 Inch.

PUMPING-ENGINE.

And.w Reid & Compy L.td Newcastle on Tyne

designed by the author for the Waihi gold-mine in New Zealand; it is the second engine of the type working on that mine. The illustrations also show the method employed in lowering the sinking-pumps.

LIST OF DRAWINGS ON PLATES VI. AND VII.

Fig. 1.—Indicator-diagram showing the mean force of a waterworks-engine.
Fig. 2.—Indicator-diagram showing the mean force of a mining-engine.
Fig. 3.—High-pressure and low-pressure indicator-diagrams.
Fig. 4.—Indicator-diagrams referred to the low-pressure cylinder.
Fig. 5.—Indicator-diagrams showing the mean force.
Fig. 6.—Diagram-section of a compound Cornish pumping-engine.
Fig. 7.—Cross-section of a compound Cornish pumping-engine.
Fig. 8.—Plan of a duplicate compound Cornish pumping-engine.
Figs. 9 to 13.—Sections, etc., of compound Cornish pumping-engine, pump-work and pit-work at the Waihi mine, New Zealand.

Mr. A. L. STEAVENSON (Durham) said that Mr. Davey stated in his paper that "the thermal efficiency is equal to the heat utilized divided by the heat supplied;"* the members were not told how to measure the heat supplied, but he (Mr. Steavenson) imagined that it would depend upon the analysis of the coal. Again, the author said "taking the initial pressure as 40 pounds, we have as the efficiency-ratio (10·7 ÷ 11·36 =) 90 per cent."† He did not know whether this was the author's explanation of it, but he ventured to ask whether Mr. Davey proposed to take the heat afforded by the analysis of the particular coal he was using, and if he did so, whether he should not remember that much depended on the class of boiler that he was using, upon the man who was firing the boiler, the way the pipes were covered, and the way in which the water was heated before it was put into the boiler; as he thought that all these things should be taken into account. Further, Mr. Davey stated that "the distribution of steam in the Cornish engine is one peculiarly adapted to the working of pumps, by the wellknown system of pump-rods. The weight of the pump-rods and attachments performs the function of a fly-wheel, thereby admitting of expansive working in the cylinder."‡ He would like to ask Mr. Davey one or two questions: Was it not a fact that a pumping-engine might be taken as a rule to work better without a fly-wheel? If one watched, as he

* *Trans. Inst. M.E.*, vol. xix., page 153. † *Ibid.*, page 157.
‡ *Ibid.*, page 155.

had done, a fine old pumping-engine in Cornwall, when it came out of the house it took from 5 to 10 seconds rest and gradually came back with its load, putting no great strain on the machinery. But if they once put on a fly-wheel, it acted not merely as a reservoir of power but as a powerful means of straining the engine, and therefore if it was possible to have an engine without a fly-wheel he thought that would be a step in the right direction.

Prof. H. Louis (Newcastle-upon-Tyne) said that although engineers understood the economy produced by compounding when an engine was doing work all the time, the case was different when, as in the Cornish pumping-engine, work was only actually performed during one-half of the time of running, namely, on alternate strokes. As he understood the action of a Cornish pumping-engine, the engine did not pump the water, thus, in the case of a deep pit, with a suction-pump at the bottom and all the rest forcing-pumps, with a properly balanced engine, the engine had only to lift the rods, and the rods as they fell back, then forced the water up the pit. Or at any rate, the rods were partially balanced, leaving only a sufficient excess of weight to force the water to the surface.

It seemed to him that Mr. Davey was making one of the cylinders of his compound engine do part of that forcing work, as he was actually putting force on that side of the stroke which in ordinary pit-practice they had to balance. He asked Mr. Davey how he balanced his pit-work when applying his compound pumping-engine in ordinary practice to deep pits.

Mr. Henry Hall (H.M. Inspector of Mines) enquired whether the principle was involved that a single engine not compounded had a limit to which they might apply steam-pressure, and whether the Cornish engine was unique in that respect, or did the theory apply to all engines not compound? Of course it had been the usual practice at collieries lately with regard to every kind of engine to raise the pressure of steam from 50 to 60 pounds up to 80 or 90 pounds per square inch without compounding the engine.

The Rev. G. M. Capell suggested that, if expansion was carried to too great an extent in a single cylinder, power was lost by the cooling action of the sides of the cylinder.

Mr. H. Davey, replying to the discussion, said Mr. Steavenson

had commenced his remarks by saying that if they were to take the thermal efficiency of the steam-engine as the standard, why should they not consider the heat supplied by the coal or the heat due to combustion of the coal and also the efficiency of the boiler? He (Mr. Davey) thought that in dealing with steam-engine questions, they simplified matters very greatly if they had nothing to do with coal or boilers but took the steam-engine entirely on its own merits and found out what it was doing with the heat which passed the stop-valve. They could find that from well-known steam-tables, which gave the quantity of heat contained in a pound of saturated steam at a given pressure and temperature. If heat had been obtained from the waste-heat of the engine, it should be deducted because the engine had not used it; it had used it in one sense, but it had given it back again. What he meant in his paper by the heat supplied was the heat passing the stop-valve, altogether apart from the heat which might be put into the furnace. That raised another question, and it very often happened that an economical steam-engine was erected in combination with an uneconomical boiler, and was used with bad coal and with bad stoking, and so on. This was a question which must be dealt with separately from that of the engine itself, unless they were going to be led into errors by debiting or crediting to one or another what ought not to be so debited or credited.

Mr. A. L. Steavenson had also quite pertinently raised a question as to the efficiency of a fly-wheel attached to a pumping-engine. In his paper he had stated that the reciprocating pump-rods of the Cornish engine performed the function of a fly-wheel, but that was a term which he thought was not very happily selected, because it had given rise to some little misapprehension, especially on the part of some of the speakers who followed. He said "performs the function of a fly-wheel";* what he meant was that having started the rods from a state of rest and put them into a state of motion, and then to bring them again from a state of motion to a state of rest, involved the operation of putting energy into a mass and taking that energy out again; and that was precisely the function of a fly-wheel. He would enlarge upon this in reply to Mr. Steavenson's criticism, and it would answer another question which had been raised. The work of the pump was represented by a rectangle. If steam were used expansively

* *Trans. Inst. M.E.*, vol. xix., page 155.

it must have a higher pressure at the beginning and less at the end of the stroke, but the area of the diagram was exactly the same. The diagram was equated by using a fly-wheel, or the use of reciprocating pump-rods. He thought that he had made clear what Mr. Steavenson was saying in favour of having an engine without a fly-wheel. It also at the same time answered another question as to why the Cornish engine should be compounded. He thought that he had explained that the Cornish engine was not without the equivalent of a fly-wheel, for if it had not a fly-wheel as generally understood, it had its mechanical equivalent. He thought that Prof. H. Louis was labouring rather under a misapprehension as to the construction of the pumping-engine itself, which would be made clear on referring to the diagrams. He (Mr. Davey) could quite understand that there should be that misapprehension because it was not very clear how the engine was so constructed that, although the pistons were moving in opposite directions, they were both employed in lifting the pump-rods, and had nothing to do with forcing them. Steam was admitted below the high-pressure piston and lifted it up, and on the completion of the stroke the steam was transferred from the bottom to the top side of the piston. During the next stroke, the steam, which in the previous stroke had been transferred, passed into the low-pressure cylinder, so that both pistons were taking steam at the same time (Fig. 6, Plate VI.). This explanation solved the apparent difficulty of so arranging the engine that both pistons were taking steam at the same time, and both making the idle stroke at the same time, so that the operation of the engine was exactly as if the low-pressure cylinder had been placed on the top of the high-pressure cylinder and had been connected directly on to it. The balancing of the engine was done in the usual way, and if the plant was properly designed at the beginning there was little weight to be taken off.

The limit of steam-pressure was peculiar to the old Cornish engine for the following reason: he had already explained the work done in imparting energy to the mass of the pump-rods: that of course was a constant for a given velocity, and practical working determined the maximum velocity to be given to the pump. This limit to the velocity of the pump-rods at once gave a limit to the expansion. Four expansions was the limit. They could not give greater velocity or else they would break the pump-rods, and

hence the limit of speed at which the engine could work comfortably. In other words they could not utilize a pressure of more than 40 pounds per square inch which would give the four expansions. At 40 pounds pressure and four expansions, the rods would attain a velocity of something like 600 feet a minute.

The members would notice the difference in the table of the efficiencies between condensing and non-condensing engines, and it was important to know what were the relative possible efficiencies. Engineers knew very well that the non-condensing engine must necessarily, if it was a perfect engine as compared with a perfect condensing engine, use more steam;* but it might be interesting to know as a matter of fact that it did give a higher efficiency ratio than the condensing engine, although working with far less economy. He desired to emphasize the importance of the little table which gave what Dr. Rankine and other great thinkers thought was the maximum efficiency of a perfect steam-engine, and they determined it on quite rational grounds. Taking the steam-engine as it stood and supposing no losses, what steam would it consume? If an engine consumed more steam than was shewn in the table, they had only to divide one by the other, to get the efficiency ratio, that is to say, the table could be referred to as a standard.

The CHAIRMAN moved a vote of thanks to Mr. Davey for his valuable paper.

Mr. H. HALL seconded the motion, which was cordially approved.

The following paper by Mr. AXEL LARSEN on "Liquid Air and its Use as an Explosive" was read:—

* *Trans. Inst. M.E.*, vol. xix., page 154, Table I.

LIQUID AIR AND ITS USE AS AN EXPLOSIVE.

By AXEL LARSEN.

Some 10 or 15 years ago, any one catering for the general reading public could be almost certain of attracting attention by heading an article "A new explosive." Though less so now, the subject still retains its charm, and whether it be the war-correspondent's vivid records of "lydditing the enemy" or his stay-at-home colleague's description of "anarchists' outrages," the explosive element of the article is sufficient to prevent it from being skipped by most readers. Those, however, to whose lot it has fallen to become more intimately acquainted with these substances, have seen so many "new" explosives come and disappear that the announcement of a fresh one evokes but a passing wonderment as to what prefix to "—ite" will form the name of the next. And yet, no little amount of interest was awakened amongst mining engineers and others when, a few years ago, it was for the first time proposed to use liquid air as an explosive; and it must be admitted that the proposition possessed many points of inducement.

Since the successes attained by Messrs. Cailletet, Pictet, Olszewski and Dewar in the liquefaction of gases, great strides have been made, notably by Prof. Linde, of Munich, in perfecting both the apparatus and the method of liquefying atmospheric air. The former used a system of treble evaporation by means of three liquids of increasing volatility, namely, carbonic acid, ethylene and oxygen, whilst Prof. Linde in Munich and Mr. Tripler of New York found that not only could the necessary cold be produced without any auxiliary refrigerating agent, but that it could be obtained automatically and continuously by the air itself.

Without going into details, which are outside the scope of the present article, it may be opportune to briefly review the working principle of the Linde liquefier. Starting from the wellknown fact that atmospheric air is not a permanent gas, and that, if it be brought from a high state of compression to a lower one, cold is produced, Q, according to the formula:—

$$Q = 0{\cdot}276\ (p_1 - p_2)\left(\frac{273}{T}\right)^2;$$

in which $p_1 - p_2$ represents the difference of pressure in atmospheres, and T the absolute temperature of the jet.

Prof. Linde constructed a machine which (1) accumulated the cooling effect, represented by the above formula, by an arrangement of two concentrically coiled pipes, through the inner of which the cooled air flowed in a reverse direction; and in which (2) re-expansion of the compressed air was stayed at a pressure still considerably higher than that of the atmosphere. By the former contrivance, the difficulty of enormous differences of pressure is obviated; and, by the latter, the work of compression is greatly diminished; for it must be borne in mind that while the cold produced depends upon the difference between the two pressures (in this case 220 and 20 atmospheres) the work of compressing the air depends on the quotient or ratio of the same. It is clear therefore that the smaller the value $p_1 \div p_2$, the better, and that an essential advantage is gained by not letting p_2 fall to unity. Indeed, but for the ingenious application of these known physical data to the practical construction of his apparatus, Prof. Linde could not have achieved the important result of making the liquefaction of air an industrial success.

One of Prof. Linde's liquefiers, which was exhibited at the Society of Arts some few years ago, produced, if the writer remembers correctly, 1 litre of liquid air per hour, whilst consuming about 3 horsepower. Since then the inventor has introduced machines capable of producing as much as 15 gallons per hour. Speaking generally, it requires about 9 horsepower-hours to make 1 gallon of liquid air. The cost of production is therefore very moderate where cheap power is available, and it is not to be wondered at that speculation grew rife as to the future possibilites of this interesting liquid.

This was particularly noticeable in the United States of North America where liquid air had a large amount of free advertisement. On one occasion it was exaggeratedly, although apparently in good faith, described as "a new substance which promised to do the work of coal, ice and gunpowder at next to no cost." But sceptics soon proved by figures the obvious fallacy of the proposition. The company-promoter, however, did not allow the opportunity to slip, and liquid-air companies were formed both in New York and Boston. Prospectuses worded with the inimitable *élan* of the

American advertiser were largely circulated, and the public was asked to believe the most incredible stories about liquid air, one of its alleged merits being its adaptability to gold-extraction. It is more than probable that the promoter succeeded in proving that peculiarity to his own satisfaction, but as far as the public was concerned most of these liquefaction-concerns only accomplished the liquidation stage.

Meanwhile, however, work of a more serious character was undertaken. Amongst other peculiar properties of liquid air, it had been found that in combination with carbonaceous substances it formed an explosive compound, and numerous experiments were made in different countries with the view of applying it to blasting. The first practical trials were made in a colliery in Germany about three years ago, but no details are at the writer's disposal. These trials do not appear to have been very successful, however, and were soon abandoned. Since then, trials have been made at different places, but the most important of these have been made, and are still being continued in one of the largest explosives works on the Continent, the carbonite-factory at Schlebusch. Here many different mixtures were studied, both as regards explosive strength and safety of manipulation, whilst Prof. Linde endeavoured to turn the results so obtained to practical account by getting the system introduced in the Simplon tunnel.

Economy was of course its chief attraction, but other points of importance remained to be satisfactorily proved. As the working conditions in the Simplon tunnel are in more than one way very different from those met with in ordinary mining, as will be seen hereafter, the investigations at Schlebusch were of course pursued with a particular object and therefore from a somewhat special point of view. At the same time, the questions involved and the conclusions arrived at possess great general interest and value.

For the sake of clearness, it may be convenient, briefly, to describe the method of blasting employed at the Simplon tunnel. The advance-heading and working-face measure about 10 feet by 6½ feet. (The full tunnel-profile will be 16 feet 5 inches by 18 feet 1 inch when completed.) Ten boreholes are usually bored for each series or "attack." Eight holes are put, one pair in each corner bored straight ahead, the remaining two being drilled obliquely

so as to form a centre cut. Two or three holes are bored simultaneously. The holes are from 6 feet to 6½ feet deep, and about 3¼ inches in diameter. Hydraulic boring-machines are used: in principle they are of the usual type, but improved in detail. The drills can be arranged to bore holes up to 6 inches in diameter. Each hole is charged according to the hardness of the rock, with from 13 to 22 pounds of blasting-gelatine. The total consumption of explosives in the tunnels averages about 1 cwt. per running yard.

The driving is for obvious reasons a race against time, and every device is used, every nerve strained in order to save the precious minutes. The most modern apparatus is used throughout, except only as regards the lamps; these are open and of the oldest Roman type. Naked lights mean more light, however, and that, of course, means saving of time; hence the preference. But a liquid-air explosive could not be taken into places where naked lights were used without running very great risk of accident, at least with the mixtures that had been tried up to that time.

Carbon-carrier.—One of the problems to be studied was therefore to find a suitable carbon-carrier. A number of these have been tried, but most of them involve a considerable amount of danger; not only are they highly inflammable after being soaked with liquid air, but when ignited they often detonate immediately and with great violence.

The following are some of the mixtures which have been tried: —Three parts of kieselguhr and two parts of tar-oil burnt violently with long flaring flame, but did not always detonate. Equal parts of kieselguhr and of benzol proved very dangerous. Petroleum or benzol, when used alone, proved highly dangerous. The addition of charcoal or soot did not materially reduce the danger. On the other hand, the heavier and solid hydrocarbons, paraffin wax, etc., appear to render the mass less inflammable, especially when mixed in equal parts with powdered charcoal. Very good results have lately been obtained with a mixture of equal parts of paraffin and of charcoal.

Preparation of Cartridges.—Several methods of preparing the cartridges have been adopted. Either a wrapper was first filled with the carbonaceous material and bodily dipped in liquid air until completely soaked, or the liquid air was poured into the

filled wrapper. A third method has been used, by which the carbon-carrier was mixed in a wooden basin and the liquid air gradually added; the resulting paste was then transferred to paper cartridges covered with asbestos. The first method is undoubtedly the only one worthy of consideration in connection with practical mining. It is not nearly so wasteful as the two other methods, and the whole of the cartridges required could conveniently be prepared aboveground.

The liquid air would be taken down into the mine in large "ammunition-boxes," preferably on a wheel-base, and sent into the different working-places like ordinary empty-tubs. Rectangular wire-baskets filled with cartridges would be taken down at the same time and placed in the liquid. By the time the boxes had arrived at the shot-firing points all the cartridges would be fully soaked, but they would, of course, remain in the liquid until immediately before being placed in the shot-holes. The wire-baskets would be found convenient for keeping cartridges of different diameters separately, and also for lifting and replacing the same without having to dip the hands into the liquid, although such short immersion would prove neither painful nor injurious.

The writer fancies that such "ammunition-boxes" would meet with no objection on the part of the workmen, but rather would become general favourites, for in many hot workings they would act as splendid air-coolers and purifiers. It is, however, probable that the preparation of blasting-cartridges, as above described, would be a "manufacture" within the meaning of the Explosives Act, and that therefore a licence would have to be obtained from the proper authorities—a somewhat awkward contingency.

Cartridge-wrappers of felt have been used, but they are more expensive than paper, and offer no comparative advantages. Fluted cardboard or paper, such as is commonly used for packing glass bottles, etc., is perhaps the most suitable wrapping-material.

A cartridge 8 inches in length by $2\frac{3}{4}$ inches in diameter, when filled with a mixture of kieselguhr, tar and tar-oil, weighs $11\frac{3}{4}$ ounces. It absorbs $24\frac{3}{4}$ ounces of liquid air, thus showing a total weight of 2 pounds $4\frac{1}{2}$ ounces. The time occupied for fully soaking the cartridges is about 10 minutes.

Life of Cartridges.—The life of a liquid-air cartridge is, unfortunately, but ephemeral when once it has been removed from

its vital fluid. A cartridge of the above-mentioned dimensions would have to be fired within 15 minutes after being taken out of the liquid, to avoid a miss-fire. A larger cartridge would, of course, have a better chance, but a thinner one much less.

Mode of Detonation.—Liquid-air cartridges are best detonated with a small guncotton-primer and detonator. Dynamite primers, such as are used for blasting-gelatine, are useless, as they would immediately freeze.

Explosive Strength.—It would of course be useless for any practical purposes to attempt to determine, with any approach to accuracy, the strength of an explosive compound where one of its chief ingredients is continually escaping. But the problem becomes still more involved through the manner in which the evaporation of liquid air takes place. During the process of liquefaction, both elements of the air are liquefied simultaneously, but during re-evaporation the nitrogen, being the more volatile of the two, escapes more quickly than the oxygen; at least up to a certain point. Thus, for example, the liquid air used for blasting experiments near Vienna last year was transported in flasks provided with the Dewar vacuum-jacket and packed with felt and cotton in wooden cases. When despatched from the works in Munich, the liquid contained oxygen and nitrogen in the ratio of 75 and 25, but before the experiments took place, some 72 hours later, half of the liquid had evaporated—the remainder containing 85 per cent. of oxygen.

The explosive effect to be derived from liquid-air cartridges depends therefore (1) on the "freshness" of the liquid, (2) on the selection of carbonaceous material, and (3) on the time of exposure. The latter is without a doubt the most important consideration, and, besides, the most difficult to adapt to practical requirements. Cartridges of small diameters, such as are met with in ordinary mining, would appear to require quite exceptional working conditions to allow of their being used with advantage. Even cartridges of large diameters, say 3 to 4 inches, require very quick handling. The rapid surface-evaporation soon creates a coating of inert material around the cartridge which, acting like an empty space, causes a considerable loss of pressure.

Again, the absorptive power of the carbon-carrier, as well as the amount of carbon contained therein, are important factors

to consider. A carrier rich in carbon, but of inferior absorbent capacity, would, if the cartridge be exposed too long, leave such an excess of carbon monoxide in the fumes as to make it unsafe for underground work. Broadly speaking, it may be said that with certain admixtures, notably of the petroleum variety, and by using highly oxygenated air, it is possible to obtain an explosive compound of greater strength than blasting-gelatine. But these mixtures are, as already mentioned, highly inflammable, and therefore dangerous to use. The safer mixtures are of lesser strength. Owing to the rapid evaporation, however, a reliable standard of strength is not obtainable in any case.

Conclusions.—The reader will doubtless already have drawn his own conclusions from the above brief remarks, which will probably not lean towards anticipating a speedy introduction of "oxyliquite," as it has been proposed to call this new explosive agent. However, it would be unfair to repudiate a new-comer so soon after its baptism, seeing that it may yet possibly have a long and honourable career before it.

After the chief engineer's (Mr. Brandt's) death, the Simplon experiments were discontinued; nevertheless much attention is still being devoted to the matter in Germany, where investigations are at the moment being prosecuted in three different centres. Already several of the practical difficulties indicated in the preceding remarks seem to have been minimized, although much still remains to be accomplished before the question is satisfactorily solved from the practical miner's point of view. Meanwhile, mining engineers in this country will probably watch further progress of the matter with considerable interest, and should any information on the subject reach the writer, he will have great pleasure in communicating the same to the members of the Institution.

The CHAIRMAN moved a vote of thanks to Mr. Larsen for his interesting paper.

Mr. M. WALTON BROWN seconded the motion, which was cordially approved.

Mr. H. D. HOSKOLD'S "Notes upon Ancient and Modern Surveying, etc.," were read as follows:—

NOTES UPON ANCIENT AND MODERN SURVEYING, AND SURVEYING INSTRUMENTS, BOOKS, TABLES, ETC.

By H. D. HOSKOLD.

It would be exceedingly difficult, if not absolutely impossible, to determine how far back the nature, relation and application of lines and angles began to be studied and employed as a useful art in astronomical determinations, and for the formation of plans, sections, execution of works, and in the graphic representation upon maps of a part or the whole of the earth's surface.

The recent important discoveries in Egypt and other parts have, however, placed it beyond doubt that mathematics, engineering, etc., were known and practised to a large extent at a very early period, as demonstrated by the gigantic works executed some 4000 or 5000 years B.C., by King Menes I., in diverting the Nile from its ancient course, enabling him to build his new capital, Memphis, upon its western bank: the great hydraulic exploits of King Amenemes III. in planning and executing the tunnels, embankments and sluices, required for the formation of an immense artificial lake, which he made in a great depression in the desert-limestone, to prevent the river Nile from flooding the cultivated lowlands: the astronomical books compiled for the library of King Sargon I.; and the various other important and extensive works of different kinds carried out in those ancient times.

Reference has been made by historians to an ancient Sanscrit manuscript, in which it was stated that the Chaldeans estimated 4,000 steps of the camel to be equal to 1 mile, and that 62·25 of such miles were equal to 1 degree, and further, that from those data, 24,000 miles were deduced as the circumference of the earth.

Certain curious, extraordinary and interesting proportions discovered to exist in the dimensions of the Great Pyramid of Egypt, afford abundant evidence that the founders determined, by some means, the relation which exists between the diameter and the cir-

cumference of the earth, with a very near approach to the truth. The late Mr. R. A. Proctor and others were induced to conclude that an arc of the meridian must have been measured with a very considerable degree of accuracy, to enable the Egyptians to estimate that in the latitude of the Great Pyramid—calculated by Nouet at 29 degrees 59 minutes 49 seconds—the length of a degree upon the meridian measured 363,636 British feet.

It is recorded that Jomard estimated the length of a degree of the meridian, in the latitude referred to, to be equal to 363,684 British feet. The measure of a degree, as recorded in the Great Pyramid differed by only 48 feet from Jomard's calculation. Prof. Francœur's geodetical tables, published in 1879, were calculated from formulæ involving the flattening of the earth, introducing every requisite to insure accuracy according to modern scientific principles, and these tables exhibit the length of a degree of the meridian in latitude 29 degrees 59 minutes 49 seconds to be equal to 363,681·909 British feet, differing by only 45·909 British feet from the length said to be indicated in the Great Pyramid. However, Prof. Piazzi Smyth made the latitude to be 29 degrees 58 minutes 51 seconds.

If the authorities indicated are thoroughly reliable—and there is no evidence proving that they are not—we have here a most curious coincidence between ancient and modern determinations, proving one of two things, *i.e.*: that the ancient world possessed greater scientific means at its disposal than is known or generally believed, the evidence of which is lost by the destruction of the inestimable Alexandrian libraries; or that the scientists have erred in their conclusions as deduced from the Great Pyramid data.

The great and celebrated philosophers, Pythagoras, Thales, Anaximander, Archimedes, and Eratosthenes, and others, have each, in turn, been made to claim the honour of announcing the earth to be spherical, and also of determining its circumference.

In or about 76 B.C., Posidonius is represented to have determined from astronomical observations, which he made upon the star *Canopus* at Rhodes, and also at Alexandria, that the circumference of the earth amounted to 240,000 stadia. Letronne stated that Posidonius employed an amplitude-arc of 5 degrees, and Strabo thought that the length of this arc amounted to 4,000 stadia, and estimated from it that the circumference of the earth amounted to 288,000 stadia.

The celebrated geographer and astronomer, Ptolemy, determined the circumference of the earth to be 180,000 stadia, and consequent upon his having stated that a Chaldean mile equalled 7·5 stadia, Posch considered that Ptolemy obtained his information from some ancient Chaldean documents, accessible at that time.

It is understood that in or about 827, one of the Arabian chiefs caused astronomical and geodetical observations to be made in order to determine the circumference of the earth; and, in 1322, Abulfeda, the Arabian geographer, is reported to have determined that from the northern portion of the measured arc, 56 miles were deduced as the length of 1 degree while, from the southern arc, 56·25 miles were obtained as the length of 1 degree, or equal to about 71 British miles.

In the copper-mines of Wady Magerah, in the peninsula of Sinai, historic and artistic scenes have been found pictured upon the rocky walls of the mines, and an opinion has been expressed by the learned in such matters that these form one of the oldest inscriptions in the world, probably 6,000 years old. King Snefura is mentioned and represented in the inscription in the act of "conquering an Arabian or Asiatic enemy." Snefura is said to have been a King of the third Egyptian dynasty, who reigned about 4000 B.C. It is thought that the chiefs of the copper-mines made the sculptured picture, which would seem to indicate that great progress had been accomplished in the arts and sciences then known. It is natural, therefore, to conclude that no difficulty could have been experienced in making surveys and plans of the copper-mines of Wady Magerah. That such a practice really existed is proved by the map of an ancient Egyptian gold-mine constructed upon papyrus about 1400 B.C., which document is preserved in the Turin museum; doubtless, however, other maps of more ancient date will, in course of time, be brought to light.

In the British Museum, London, also exists an old papyrus written about 1600 or 1700 B.C., which, however, is considered by competent judges to be only a copy of an older one. Its contents consist of rules for the calculation of areas, circles, triangles, and trapeziums. The writer has seen an account of a much older and more important papyrus, but where it is recorded has escaped his memory.

Hero, in one of his books, written between 250 and 286 B.C.,

describes such problems as were then in use and applied to surveying operations. He also introduced improvements in such instruments as were in use at his time, one of which he named diopter. The whole of the remaining works of Hero may be found in the collection entitled *Veterum Mathematicorum Opera*, published in Paris in 1693. An Italian work translated by Gio Batista, 1589, in the possession of the writer, shows that Hero was far advanced in the science of hydraulics.

The great Ptolemy is said to have possessed a circle engraved upon stone—most probably in part metal—by which, in his observations, he was enabled to estimate angular measure to single minutes, which seems to be confirmed by the scientific determinations of his predecessors as also by Hipparchus, the discoverer of the precession of the equinoxes and parallax of the moon. The principal circles of Ptolemy and of others previous to his time seem, however, to have been large in diameter, so as to permit of such fine divisions and resulting accuracy; for we have no evidence proving that the ancients knew anything about vernier-scales and micrometer-microscopical instruments for the determination of small fractions of a degree or of a minute of arc.

The small portable instruments, used by Ptolemy in obtaining the altitude of celestial objects, consisted of two circles, one working concentrically within the other in the same plane and upon the same axis. The opposite ends of the diameter of the inside circle carried prisms for facilitating the observations, and under one of these an index or fine point was placed to mark the angle. If we were to suppose that the divisions upon the inner circle differed from or had some ratio to those on the outer circle, then, an approach to a vernier-scale would have existed; but Ptolemy does not appear to have hit upon that plan, for he is completely silent upon the subject in his celebrated Syntaxis. The astrolabe used by Hipparchus and Ptolemy carried "circles representing the equator, ecliptic and other principal circles of the celestial sphere." It is interesting to note that two circular instruments made of copper were fixed in the square portico of the old museum of Alexandria for astronomical observations. It also appears that the Greeks divided their instruments to every 10 minutes; but the instruments of the Arabians, generally, were larger and better constructed than those of the Greeks.

The wellknown geometrical elements of Euclid—who lived

in the time of Ptolemy I., between 323 and 284 B.C.—were first printed in Europe at Venice in 1482, and, as stated by Day, in England in 1570, possessing as they do the basis of mathematics for all time, were probably founded, in part, upon much older propositions of a similar nature, especially those of Eudoxus and Theætetus; but Euclid must have applied his rules to practical surveying in Egypt, to a very large extent.

When in ancient times, simple surveying and engineering operations first became a necessity, the instruments employed must have been exceedingly rude in construction—much more so, in fact, than the rectangular diopter sighting-instrument which Hero invented, and employed in measuring angles and in determining levels—and they probably consisted for the most part of two horizontal cross-bars of wood or metal mounted so as to revolve around a pin or axis, fixed in the top of a stout rod, the lower end being thrust into the ground. Possibly, the upper revolving parts of the instrument may have been placed upon a square board as a common plane-table, and the horizontal angles formed between the cross radial bars representing the plain sights may have been measured upon the plane-table by applying a straight-line rule divided as a scale of equal parts, similar to the form of rule applied to a navigator's cross-staff in 1514, or as in the form adopted by Ribera in 1529 and others; that is to say, form the three sides of a geometrical square upon the plane-table, the rules or sides of which were divided to represent angular or straight-line measure.

Although it has been stated that there is no positive evidence to hand proving that circles, or arcs of circles, were used in the ancient world earlier than the time of Ptolemy, still, in some of the Chaldean records, recently discovered, and referring to the Arcadian period some 4000 or 4500 B.C., mention is made of an iron wheel (circle); and, taken in connection with the earliest records, it has been stated that "before any historical period the year had been divided into 12 months, the course of the sun mapped out among the stars, and the zodiacal and twelve constellations established."

There is, therefore, strong inferential evidence that the ancients possessed portable circles, or arcs of circles (wheels) for use in their astronomical and land-surveying operations. This idea is confirmed by the fact that in 1874, the late Mr. George Smith, of the British Museum, discovered an astrolabe or angular measur-

ing-circle in the ruined library of the Palace of Sennacherib, of about 705 B.C., but there were no means of determining its age or how long previously such instruments had been used. The circumference of the astrolabe was divided into 12 equal parts, with the signs of the zodiac, months of the year, and the number of degrees in each marked upon it. An inner circle was also engraved upon the instrument and divided into 24 equal parts, and in each of these one of the principal stars was inserted. Thus, not going farther back than Sennacherib, we have positive evidence of the existence of a circular angular measuring-instrument at least 2600 years old.

Bailly, in his history of ancient astronomy, stated in 1781 that the ancient astronomers—date unknown—employed copper circles of large diameter placed in the meridian, and also others at right angles to that plane. Also that Hoang-Ty, a Chinese emperor, invented the cycle of 60 years, 2600 B.C., as also various astronomical instruments, also a special one for observing the four cardinal points. It has been supposed that this instrument was a magnetic compass.

The very high degree of accuracy obtained in astronomical determinations in India by the ancient natives is remarkable; but whether their first operations were carried out at a prior or subsequent date to those of the Chaldeans and Egyptians is uncertain.

However, it is worthy of note that Aryabhata early in the sixth century determined the diurnal revolution of the earth upon its axis, as also that the circumference of the earth amounted to 25,080 miles.

The early observers in India possessed brass circles of comparatively small diameter; but it is reported that the imperfection of the graduations, wearing of the axis of the circle, etc., caused them to be abandoned for others of larger diameter, many of which were built up of masonry; the circular part or limb intended to receive the graduations being made of marble. The distance between each division enclosing a degree amounted to 2·833 inches, giving a diameter to the instrument of 27·01 British feet. There were, however, others of the same class much larger, and various observatories containing such instruments existed in India in 1777. It is recorded that one of those ancient astronomers of India determined the north latitude of a certain place to be 23 degrees

10 minutes 0 seconds, and when tested by modern observers with fine instruments, the error discovered amounted to no more than 24 seconds of arc. Soon after, in 1787, Burrow, a great mathematician and Indian geographer, stated that the Hindus knew the binomial theorem.

No doubt the larger stone circles, which Ptolemy is said to have possessed, were similar to the Indian instruments previously referred to.

Ogilby, in his *Itinerarium Angliae*, a rare, curious and interesting book of roads and surveys made in England in 1674, by order of King Charles II., states that the Persian monarchs commanded an exact register to be made of the distance traversed from station to station through their dominions. The great Macedonian conqueror also had his *Mensores Itinerum Alexandri.*

Whenever the Romans undertook military expeditions it was customary to note the distance from one station to another, including the names of cities and towns, and it is recorded that Julius Cæsar composed an universal itinerary. Be this as it may, we know that the records constituting the ancient itinerary of Antoninus, contain a survey of distances between all the stations or towns occupied by the Romans in Europe and other places. One of the principal stations upon the African continent was at Alexandria; but the measured distances were continued through a succession of towns which then existed along the eastern and western banks of the Nile, and measurements were continued through the whole country. This old itinerary, or survey-book of roads and lines traversed, is believed to have been compiled in the time of Hadrian; but it contains no evidence that any horizontal angles were taken. Original copies of Antoninus are exceedingly rare, and the contents difficult to understand and reconcile. A vast amount of archæological erudition has been expended upon Antoninus; and probably his oldest English-Latin commentator was Richard, the monk of Cirencester, 1357.

From the time when the Romans conquered Britain, Spain, etc., the art of surveying remained in a very rude condition for a considerable period, consequently no particular details have come down to us referring to the form of instruments employed and mode of surveying adopted during the Greek and Roman domination.

It is, nevertheless, interesting to note that there still exist

various instruments constructed at a comparatively early date. One of these is the Saracenic planisphere, or as it has been

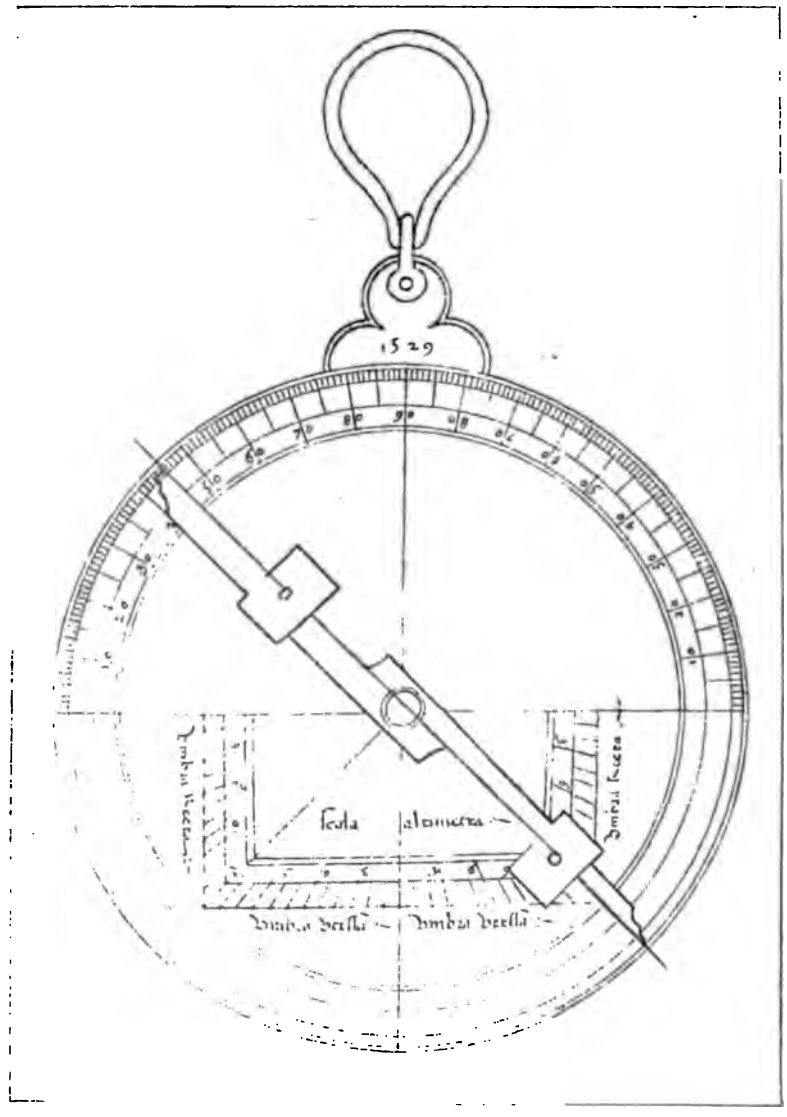


FIG. 1. —THE RIBERA SURVEYING-CIRCLE, 1529.

termed, astrolabe, made in Valencia, Spain, in 1086, and preserved in the museum of Cassel. A similar instrument, inlaid with silver

and copper, made in 1240, is in the British Museum. Various others may be traced in the cabinets of the curious.

Fig. 1 represents the circular plane-astrolabe of Ribera, 1529; it was used for taking altitudes at sea and horizontal angles on land, and, doubtless, is of a type similar to those used many centuries before. One half of its circumference was divided into degrees, and the other half contains the three sides of a quadri-

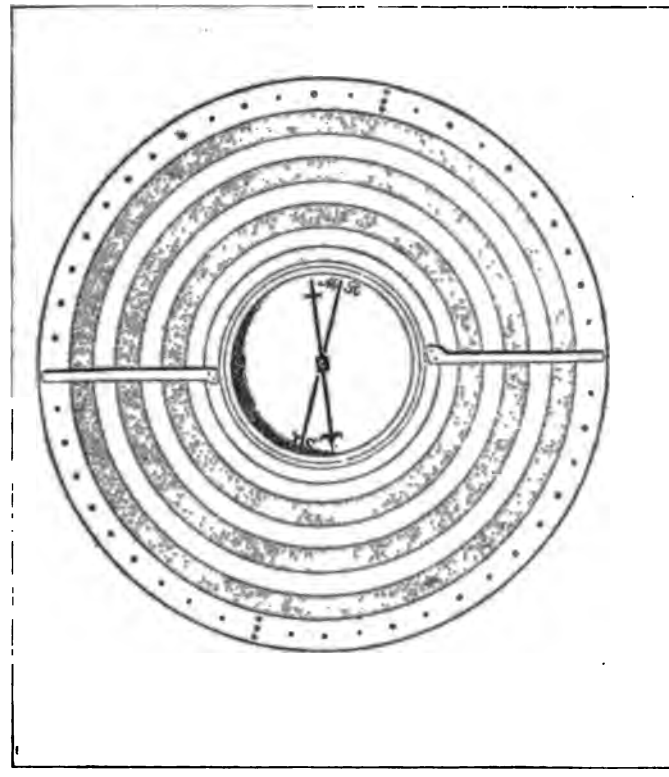


Fig. 2.—The Setz Compass for Mine-surveying, 1541.

lateral figure, each of which is graduated to correspond to certain angles on the semicircle. A pair of plain sights with radial bars were mounted upon the circle by which angles were observed.

Agricola, in his *De Re Metallica*, latin editions of 1556, 1561 and 1657, as also in the Italian translation (1563), devoted a section to subterranean surveying, and he represented a roughly drawn surveying-instrument about 6·25 inches in diameter, apparently

for the most part made of wood. At the centre, a depressed circular space was formed, about 1·36 inches in diameter, for the reception of a small box containing a magnetic needle; surrounding and on a raised level part of the face of the instrument circles were described: each half of the inner circles was divided into from 1 to 12 equal parts, each of which on the second or exterior circle was divided by shorter lines or dots into four equal parts. Several other circles were drawn concentrically to the others, and to the outer rim of the instrument; and there were also seven circular grooves filled with wax of different colours.

Before 1556, an instrument of a similar type was in use, one of which, called the Setz compass, bearing the date of 1541, is preserved at the Neudorf mines in the Harz, and for the reason that it has only three circular grooves for coloured wax, it would seem that it was intended merely for limited surveys (Fig. 2). On the contrary, however, Agricola's compass was adapted to more extended surveys, such as progressive mining required.

When Agricola's instrument was used, it appears that the small magnetic needle was made to point to the meridian, or 12 hours, then the sights were turned in the direction of the underground road, and a short line being marked upon the wax in one of the circles, its characteristic mark and length of road were entered in a book, and so the process was continued until the end of the survey. When necessary the survey was repeated at the surface, for the object of determining some particular position or boundary-line.

It is highly probable that prior to the application of the plain revolving-sights, attached to Fig. 2, some such instrument may have been used, with the addition of a cord stretched over it and in the direction of the underground road, the mark upon the wax being made to correspond with the direction of the cord.

A much older form handed down by tradition and communicated to the writer, when a boy, by an old miner aged 84 years, is that of employing a low wooden stool or round plane-table revolving horizontally, which, with a chalked line measure, was employed for underground surveying. It appears that the line was stretched in the direction of the road and that part of it over the table was raised a little, and by its sudden fall marked the direction upon the table. It would also appear, that part of this line at each operation was erased to give room for the succeeding one,

and so on alternately. After the first line had been taken, the table was set up at the next bend in the road, and the line previously marked upon the table placed in the direction of the back station and the forward bearing observed and measured as at first: this system being carried on to the end of the survey, so that a kind of rough plotting, without a scale, was practised. It is evident, however, that this plan could only have been adopted where but a few lengths were required to be measured. It is stated that this plan was practised in England, and probably introduced from Germany prior to or during the reign of Queen Elizabeth, who gave concessions of mines to German adventurers in 1568.

It is evident from a German work, published in 1505, on mining—also exhibiting a diagram of the miner's compass—that the idea of employing the needle with a divided circle might have occurred to others prior to 1505, for, it is considered that the magnetic needle was first introduced into Europe between 1310 and 1313. It is, however, known that Necham in his work (in latin) on things pertaining to ships, in the twelfth century, speaks of the mariner's compass, and also of a ship sailing from Hull called the "Plenty," directed by the "sailing-needle" in 1338.

A naked surveyor is represented in Agricola's work taking levels by means of a large vertical circle nearly as high as himself: the perpendicular line of the circle being marked by a long pendulum terminating in a pointer which marked the zero of the instrument.

It was more especially due to Fernel, that surveying was revived in Europe. In 1525, he attempted to measure a degree of the meridian, between the cities of Amiens and Paris, and his instruments consisted of a revolving wheel for measuring the distance, and an arc of a circle, called a sector, 5 feet in radius, for measuring the angles. From the operations so conducted he deduced that the length of an arc of 1 degree amounted to 365,088 British feet.

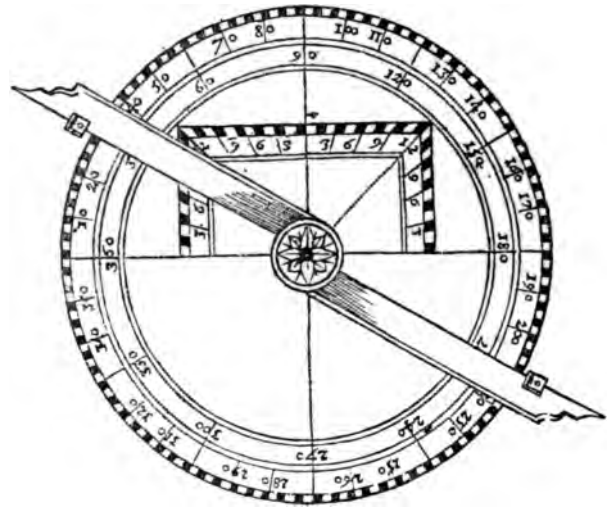
Referring to important British works on surveying, the earliest containing a general system, known to the author, is Thos. Digges' *Pantometria*, in black letter, 1571, London. In it he describes a circle 24 inches in diameter, divided at every 2 degrees, with a radial bar and plain sights revolving round the circumference. It was placed upon a staff for observations, and Digges honoured it with the name of "theodelitus." Fig. 3 represents page 35 of

Longimetra.

The 27 Chapter.

The compoſition of the inſtrument called Theodelitus.

IT is but a circle diuided in 360 grades or degrees, or a ſemicircle parted in 180 portions, and euery of thoſe diuiſions in thyrce or rather 6 ſmaller partes, to it ye may adde the double ſcale, whoſe ſingle compoſition is mentioned. The ſides of that ſcale diuided in 12, 60, or 100 partes. The index of that inſtrument with the ſightes, &c. are not vnlike to that which the ſquare hath: In the backe prepare a vice or ſcrue to be faſtned in the top of ſome ſtaffe if it be a circle as heere: let your inſtrument be ſo large that from the centre to the degrees may be a foote in length, more if ye liſt, ſo ſhall you not erre in your practiſes, the backe ſide muſt bee plaine and ſmoothe to drawe circles and lines vpon, as ſhall be declared: for a farther declaration of that I haue ſayde, beholde this figure following.



The 28 Chapter.

To ſearche the beſt proportion or ſimetrie of many places with the true diſtance approching neere none of them by the inſtrument named Theodelitus.

THis inſtrument vpon his ſtaffe or otherwiſe in the field placed vnder being in his Diameter, let it direct your ſight to ſome one place which ye will meaſure. Truely in my fantaſie it were more commodious if his diuerſitie or diameter were firſt laid in a ſtraight line, bringing the ſight to the vttermoſt place toward the left hand, ſo conueying your index to euery place or marke on the right ſide, noting diligently the Angle or Angles of poſition vpon ſome flate ſtone or table prepared, which angles heere I call the grades or degrees

FIG. 3. — THE DIGGES THEODELITUS, 1571.

this curious book, with a diagram of the instrument, as also part of his description. It will be observed that it is not much removed from the Ribera type of surveying-circle of 1529.

Fig. 4 represents an old form of a German surveying-instrument, the parts being fixed to a book which also was made part of the instrument. When the lateral telescope was directed to an object, the index-bar *o*, on the top of the book-table was moved by hand until the magnetic needle pointed to the north. The angle

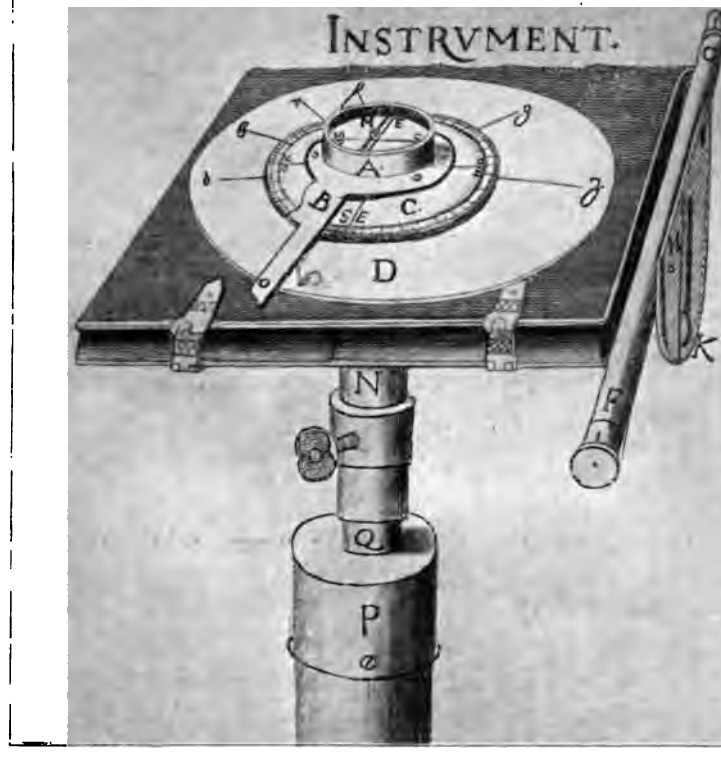


FIG. 4.—THE ALBRECHT THEODOLITE, 1673.

or bearing was then read from the point where the side of the index-bar cut the horizontal divided circle. The book was also used for writing and drawing plans. This instrument is dated 1673; but it was invented in 1625, and one of these instruments is still preserved in the museum at Nurnberg.

Various other works appeared upon surveying in the sixteenth and seventeenth centuries, such as Lebourne's, 1657; Love s

Geodesia, 1688; Gardiner's *Practical Surveying*, 1787; also Houghton's *Subterraneous Surveying*, 1681. The principal instruments employed by the latter consisted of a small magnetic compass, a measuring-cord, and a 2 feet rule: the second edition of this book appeared in 1758. Of the foreign books published during the same intervals may be noticed De Medici, 1569; Hofmann, 1612; Albrecht, 1672; Voigtel's *Geometria Subterranea*, 1686 to 1713; Widler's latin treatise, 1726 to 1763; Beyer's, 1749; Oppel's, 1749; and Duhamel's *Géometrie Souterraine*, 1787, etc.

Snellius is said to have commenced a system of trigonometrical surveying as early as 1615, and he employed a chain to measure the base line between Leyden and Soeterwood. He commenced by connecting a base-line to a series of triangles, employing an amplitude-arc of 1 degree 11 minutes 0·5 seconds. The final deduction of the length of a degree on the meridian was found to be equal to 55,074 toises, and a toise of this measure equalled 6·394,592,52 British feet. The result thus arrived at was afterwards examined by Kästner, and found to be in error to the length of about a toise; but considering that Snellius did not submit his angles to any correction for spherical excess, etc., it is remarkable that he obtained so close an approximation to the truth. In 1722, the work which he performed was verified and one degree found to be equal to 57,033 toises. On this occasion, a sector of 5 feet radius was employed to determine the angles.

In 1635, Norwood measured with a chain the distance from London to York, from which, in connection with other observations he obtained 57,424 toises for the length of the arc of 1 degree of meridian.

It is recorded that Gascoign, or Gascoyne, placed lines in the focus of a telescope, which he attached to his sector-instrument of 10 feet radius, as early as 1640. He was the first to place cross-hairs, to indicate the focus of the telescope, by which means its optical axis could be made to bisect distant objects. At the same date, he also invented and applied a micrometer-apparatus for the determination of distances: an important matter, and improperly claimed by others in more recent times. Moreover, Picard applied the telescope to angle-measuring instruments, and also placed lines to indicate the focus of the telescope in 1669. About the same time, he also measured a base-line 7 miles in length, and employed an angular instrument of the sector-class of 10 feet radius, with

an attached telescope; and from his arc of 1 degree 22 minutes 58 seconds he estimated the length of 1 degree to be equal to 57,000 toises.

The great mathematician and philosopher, Newton, had previously announced to the scientific world his grand principle of universal gravitation, and, from the investigations which he carried on, he determined the form of the earth to be an oblate spheroid, and, consequently, that the equatorial was greater than the polar axis of the earth.

The geodetic operations, performed by Picard, seem to have enabled Newton to establish his principles; but the great Englishman's discoveries induced foreign opposition and a desire to prove that Newton's conclusions were erroneous, and between 1684 and 1718, the original triangulations of Picard were extended, by J. and D. Cassini southward to Collioure and northwards as far as Dunkirk. A base-line was measured at each end, and the northern portion of their arc had an amplitude of 2 degrees 12 minutes, from which 56,960 toises were deduced as the length of 1 degree of the meridian. The southern arc of 6 degrees 19 minutes enabled the observers to obtain 57,098 toises as equalling the length of 1 degree. Thus it was made to appear that a degree of the meridian decreased northward and increased southward, leading the French scientists to believe that Newton's conclusions were erroneous; consequently serious discussion ensued between the two opposing national parties.

Cassini's error was that he believed the earth to have a prolate, and not an oblate spheroidal form. However, in 1744, the same arc was measured by Cassini, de Thuri and Lacaille, and their deductions proved that the former determinations were in error, and that instead of a degree of the meridian decreasing it actually increased northward: thus the original conclusions arrived at by Newton were established for all time. Previous to the determinations of Cassini, de Thuri and Lacaille, the French were dissatisfied; but they finally agreed to undertake, in 1735, two scientific expeditions, with a view of settling the question definitely. Peru was selected for the operations of the first, and Lapland for the second expedition. In the latter country, the angles were measured by means of a quadrant, 24 inches in diameter, fitted with a telescope and micrometer-apparatus. The

astronomical observations were made by means of a sector, 9 feet in length. The final result, as deduced from these observations, gave 57,437·9 toises as the length of 1 degree of the meridian which cuts the polar circle. The operations were afterwards examined, showing that the length of 1 degree was equal to 57,237 toises. The length of the base-line employed was 8·9 miles, and the measuring instruments consisted of deal rods, 32 feet long. Two independent measurements showed a difference of 4 inches.

The Peruvian expedition measured two base-lines, one near Quito, 7·6 miles, and the other near Cotopaxi, 6·4 miles in length. The quadrants used for measuring the horizontal angles were 24 and 26 inches in radius; but they were found to be very imperfect. Astronomical sectors were employed, of 8 and 12 feet radius. The great result, so long sought, was at length obtained by this expedition, and the determination of the length of 1 degree as deduced from these operations was found to be equal to 56,753 toises. The northern extremity of the Quito base-line was elevated 7,850 feet above sea-level; but some of the stations employed in the triangulation were elevated 14,000 feet. The southern or Cotopaxi base-line was only 1,000 feet above sea-level. The measuring-rods were daily compared with a standard Paris toise.

General Roy commenced a trigonometrical survey in Scotland between 1747 and 1755; but the results were not considered to be of the highest order, on account of the imperfection of the instruments, and this circumstance induced the general opinion that surveying circles of a superior class must be invented before accurate geodetic results could be obtained. Various surveys of an ordinary kind were, however, conducted in England between 1752 and 1755; but the instruments employed were generally of a class known as circumferentors.

The necessity for accurate instruments being thus acknowledged, the celebrated Ramsden undertook to investigate the problem, and his inherent scientific, mathematical, mechanical and general practical knowledge led to the ever memorable invention of the dividing-engine, for the purpose of graduating or dividing astronomical and ordinary surveying-circles by machinery, instead of by hand, as had been customary up to that time. The dividing-machine was completed in 1763, and a second and improved one in 1773; and Ramsden was the first to combine the altitude and azimuth-circles in a single instrument, called Ramsden's great 3 feet

theodolite, which was completed after 1773. A description of his invention exists in the *Philosophical Transactions* from 1777 to 1793. It is, however, just to remark that Bird wrote a work upon a system of graduating instruments in 1767, and he was one of the most accurate hand-dividers of his time. The history of the progress by Ramsden in experimenting upon a new method of dividing circles by mechanical means, after 10 years' continuous labour, is as interesting as it is important; because it shows that it was not until he had made various failures in detail that he ultimately succeeded. The division of a circle, or part of a circle by hand, previously and up to the time of Ramsden's discovery, was considered to introduce inequality of a serious nature between the divisions, producing corresponding fatal errors in the angles observed with such instruments; but the Ramsden dividing-engine reduced such inequalities to a mininum, and the principles involved in the mechanism which he devised has not, to the knowledge of the writer, been superseded. All that his since been accomplished is a variation in the form of the mechanical details, and in separating some of the working parts from the original divided table, in some cases causing the machine to work automatically and not by hand, as was the case in 1775, in John Troughton and Ramsden's time.

John Troughton was justly considered to be a rival of Ramsden in the art of dividing, and Edward Troughton, his brother, invented an improved method of dividing by means of micrometrical microscopes in 1785. He divided a meridian circle, 4 feet in diameter, by his method, with great success; but, in a paper upon this subject, published in the *Philosophical Transactions* in 1809, he stated that "Ramsden's method by the dividing-engine will never be superseded in the division of instruments of moderate radii." We may therefore venture to say that the division of the circumference of a circle is now performed by the delicate modern dividing-engine with almost mathematical precision.

Doubtless, a great mechanical victory would be achieved if it were possible to divide a circle in such a manner that the divisions should be absolutely equal one with another; still, in such a case, little would be gained practically on account of the entire absence of homogeneity in the particles forming the mass, causing unequal expansion and contraction of the metal employed in the construction of instruments. However, such a difference would be more appreciable in very large than in small circles.

The system, introduced by Ramsden and Troughton, was soon understood and employed throughout Europe, and from that

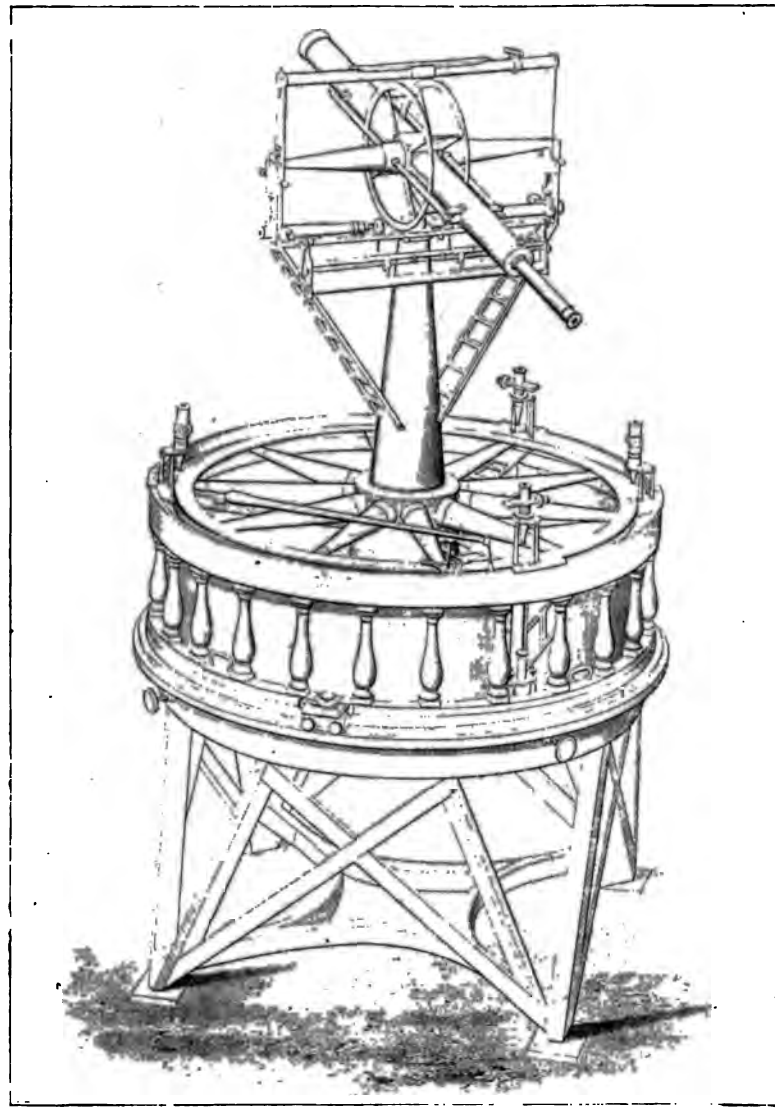


Fig. 5.—The Ramsden 36 Inches Geodetic Theodolite, 1783.

period geodetic surveying may have said to have been placed upon a more accurate and perfect basis. When Ramsden completed

his dividing-engine, he constructed a theodolite in 1780 or 1783, with a horizontal circle 36 inches in diameter, the subdivisions of which were read by micrometer-microscopes (Fig. 5). The vertical circle to this instrument was 10·5 inches in diameter, and read by two micrometers to 3 seconds of arc. It had a telescope of 3 feet focal length, and it was the first important and reliable instrument of that class constructed in England and graduated by the dividing-engine. The Royal Society of London purchased the instrument, and General Roy and Captain Kater used it upon the British Trigonometrical Survey. It is still preserved in good working condition. The telescope of this instrument commanded distances of over 110 miles. Ramsden also constructed a second theodolite of the same size, as also a zenith-sector, and standard steel chains for measuring base-lines. This second theodolite had a telescope estimated to read a fine point across water to a distance of 48 miles, but it has been used for distances up to 112 miles. It is interesting to note that this instrument is still preserved in the Ordnance Survey Offices, Southampton, in perfect working condition.

In 1784, General Roy measured a base-line on Hounslow Heath, with Ramsden's steel chain, 100 feet in length; and two independent measurements of the same line gave a difference of 1·5 inches in the total distance of 5·134 miles. The same base-line was afterwards measured by glass rods, the resulting length differing but little from the former measurements. The final measurement with a steel chain gave a difference of 2 inches. The British Trigonometrical Survey was delayed by the death of General Roy.

The surveying repeating circles employed by the French, and other foreign nations, in their geodetic operations were found inadequate to compete with the Ramsden theodolite, and the instruments made by Troughton, because the peculiar construction of the former did not insure absolute stability of the working parts, consequently the operations performed with them were inferior.

As early as 1790, an arc of 1 degree 8 minutes was measured in the East Indies, in north latitude 22 degrees 18 minutes, and Barrow deduced 56,725 toises as the length of 1 degree of the meridian. At about the same period, a commission was formed consisting of La Place, Lagrange, Delambre, Borda, Méchain, Prony and Berthollet, for the object of measuring an arc of 9 degrees 40 minutes 4 seconds, between Dunkirk and Barcelona, the object being to deduce therefrom a standard linear measure.

After these operations were completed, it was decided that the unit of the linear French measure should be equal to the 10,000,000th part of the length of the earth's quadrant from the poles to the equator, to be called a metre. The celebrated mathematicians, Delambre and Méchain, were the principal observers, and they commenced their operations in 1792. The angles of the triangulation were measured by a large repeating circle. The azimuths of the principal stations with the sun, at a fixed time, were observed; great attention was also directed to the determination of the length of the seconds' pendulum; and, finally, the latitude of the primary stations was determined by zenith-sectors. Borda's measuring-apparatus was employed in determining the length of the base-lines, of which there were two, each being 7·25 miles in length. Borda's scale, "metallic thermometer" as it was then termed (consisting of two rods, one of platinum, and the other of copper rivetted together at one end), was employed. The difference of expansion between the two metals employed in the construction of the measuring-apparatus was observed by a fine micrometrical scale. The history of this work, taken in all its details, is very interesting, especially considering that the present length of the French metre has been made a legal measure, and is the result of the combined labours of the French mathematical school and geodetical surveyors of that period. Delambre published full details of the geodetic operations in his work entitled *Base du Système Métrique décimal.*

Mudge measured various base-lines in England: that of Salisbury Plain was determined in 1794 to be equal to 36,575·64 feet, and requires particular notice on account of its having been verified in 1849, by Col. Colby's compensation-bars, and its length found to be equal to 36,577·98 feet, or a difference of 2·34 feet in the entire length in excess. Afterwards its length was again verified by a computation deduced from other geodetic operations involving the base of Lough Foyle, and was found to be equal to 36,577·34 feet in length, differing from Colby's base compensating-bar results by 0·54 foot. The continuation of the triangulation and completion of the arc of 2 degrees 50 minutes enabled Mudge to determine that the length of 1 degree in north latitude 53 degrees amounted to 57,017 toises.

As early as 1752, Lacaille measured an arc of 1 degree 30 minutes, his southern point being Cape Town, South Africa, and

he deduced 57,037 toises as the length of a degree. Maclean measured a base-line of 8·1 miles, in 1840, to verify Lacaille's determinations and after taking into consideration the effects of gravity, or disturbance caused to the plumb-line, at the northern station, which amounted to 8 seconds, Lacaille's deductions were proved to be nearly correct.

In 1845, Maclean completed an astronomical arc of an amplitude of 4 degrees 37 minutes, and Dr. Gill, the astronomer at the Cape, states that the operations conducted demonstrate "that the form of the earth in the southern hemisphere is similar to that of the northern." Baily carried on important geodetic operations in 1861; but a more general system began in 1883, carried out by Morris and Laffan, under the technical control of Dr. Gill, whose project included the Orange Free State, Natal and the Transvaal; and the triangulations have also been extended to Bechuanaland. The instruments employed are described in another part of this paper. An able paper upon this subject was read by Dr. Gill and printed in the *Report of the Sixth International Geographical Congress*, London, 1895.

In an elaborate paper, General Walker too has given very important data upon the great Indian Geodetic Survey, which also appeared in the publication alluded to.

About 1798, some geodetic operations were undertaken in Africa by Nouet, as also in other parts by different observers; but the deductions arrived at were of no great scientific interest.

The great trigonometrical survey of India was projected between 1799 and 1800, and in 1802, Col. Lambton commenced the great arc-measurement which he concluded in 1823. He was an indefatigable investigator and worker, and in carrying out the operations he employed a theodolite 3 feet in diameter made by Cary, as also a finely constructed zenith-sector, and two steel measuring-chains made by Ramsden. In order to bring the chains level, straight and to coincide with the final point in each preceding measurement of the base-line, 8 pairs of pulleys and ropes were employed. So great was the indomitable courage and anxiety displayed by Lambton, that he devoted 28 days to making 236 astronomical observations in order to determine the latitude of a single station.

In 1806, Biot and Arago commenced to extend the triangulation from Mount Mongo to Formentera, the operations extending

over two years and resulting in the completion of an arc of 12 degrees 12 minutes 13·44 seconds. Biot seems to have been dissatisfied with the 4,000 star-observations for determining the latitude of Formentera (caprice, one would conclude) for in 1825 we find him verifying his former observations and discovering an error of 9 seconds in the position.

Previously to 1821, it had been determined that the length of a degree in north latitude 45 degrees was equal to 56,027 toises. Bessel, however, found a degree in the same position to be equal to 56,964 toises, and Puissant, in 1841, obtained 57,032 toises as the length of a degree. It is important as well as interesting to note that on this occasion the principle of least squares as a correction was applied for the first time.

It does not appear that geodetic operations were commenced in Prussia before 1802.

In England, Col. Colby and Capt. Kater were occupied in 1821 in connecting the meridians of Paris and Greenwich for a second time, using for this object the stations and triangulations of General Roy. Consequent upon the lapse of time some of the stations were lost, but Kater devised an ingenious geometrical mode of discovering them. Steel chains for measuring base-lines were considered to be inefficient for accurate determinations, and were abandoned in England about 1827; and Col. Colby's compensating metal bars were introduced for measuring base-lines.

The Russians made some unimportant attempts to measure a base-line as early as 1737; but no definite results were obtained. In 1817, Col. Tenner, in connection with Struve, initiated a better system; and the former continued his geodetic operations until 1827, completing an arc of 4 degrees 30 minutes, while Struve's operations extended over an arc of 3 degrees 30 minutes. The circular instrument employed by them consisted of repeating theodolites or circles of French type, 16 inches in diameter. The lengths of the base-lines were determined by a measuring apparatus specially devised. The interval or gap, which then existed between Russia and Lapland of some 5 degrees 30 minutes, seemed to offer means for further verification of the length of a degree of latitude in high regions. It was, therefore, determined to measure this intervening arc, and operations were commenced by Struve and Argelander, and continued until 1844. Finally, the measurements were continued through Sweden and Norway, and, in this

case, the operations were conducted by Struve, Selander and Hansteen. At the end of 1855, an arc of 25 degrees 20 minutes 9·29 seconds had been completed. The Russian party employed 8 base-lines, 224 principal triangles, and 9 astronomical stations. The Scandinavian party used 2 base-lines, 33 principal triangles, and 4 astronomical stations. Although Struve had strong predilections for the French form of repeating theodolites, as also the manner of employing them, still he discovered that the periodic error of observation due to the mode of repetition was very considerable, and this led him to adopt the plan of measuring the same angle upon different parts of the graduated circle. The deductions arrived at by Struve from the measurement of his great arc of 25 degrees 20 minutes 9·29 seconds, were that the length of a degree in north latitude 53 degrees 20 minutes amounted to 57,092 toises; in 55 degrees 34 minutes to 57,116 toises; in 56 degrees 32 minutes to 57,121 toises; in 57 degrees 28 minutes to 56,956 toises; and in 59 degrees 14 minutes to 57,125 toises. It would nevertheless appear that some discrepancy arose in some of the determinations. The small number of astronomical stations employed by the Russians and the Swedish commissioners rendered this great arc-measurement of less value than otherwise would have been the case. It is evident that with a view of making further comparisons with the geodetic operations over such a great distance and the final settlement of the length of a degree of the meridian in the latitude mentioned, a greater number of astronomical stations should have been selected.

Taking advantage of the great velocity of light, General Muffling resorted to the plan of connecting the observatory of Seeberg and Dunkirk by measuring the difference of time between the stations, noting the time from powder-flashes as seen from one station to the other. In this way he deduced the amplitude to be 8 degrees 21 minutes 18 seconds. Personal error in distinguishing the moment when the light appeared, as also the distance, would seem to affect the case, and to render this plan much inferior to that of communicating the time by an electric wire, connecting the stations to some fixed astronomical observatory or station as is the practice at the present time, allowing of course for the time of transmission.

Brest was connected with Strasbourg by General Bonne between 1818 and 1823: the whole of his operations were carried

on at night, light being placed in the focus of a parabolic reflector for the signals at the principal stations, and the observations for the determination of the longitude were aided by powder-flashes, as had been practised by Muffling.

A trigonometrical survey was made in Hanover in 1820, by Gauss, his arc being 2 degrees 57 minutes, from which he calculated the length of a degree of the meridian to be 57,126 toises. He also employed a heliotrope as a signal at some of the stations.

The arc determined by Schumacher, was 1 degree 31 minutes 53 seconds and he deduced from it that in north latitude 54 degrees 8 minutes 13 seconds the length of a degree amounted to 57,092 toises. Struve appears to have assisted Schumacher.

Passing over a variety of details, and minor efforts of other persons, we come to a consideration of one of the most important and extensive national geodetic surveys on record, namely, the great trigonometrical survey of India, to which reference has been already made. The celebrated Col. Everest succeeded to the directorship of that survey in 1823, and he continued it for some time under the original organization and with the same instruments as formerly employed; but he soon discovered the necessity of adopting a new system and of introducing all the improvements which science and art could at that time afford, and for this object he went to England and superintended the construction of new instruments from about 1825 to 1829. One of them was a 36 inches theodolite reading by micrometrical microscopes, and made by Troughton; there were also two smaller ones, 12 inches in diameter each, two 3 feet vertical circles, and six sets of compensating measuring-bars; also two iron standard measuring-bars each 10 feet in length. With these Col. Everest commenced new operations in 1830: the smaller theodolites being used from the top of platforms erected 30 feet high. He also introduced the heliotrope system of throwing a ray of light to distant stations during the day, and reverbatory and argand lamps with blue lights for night use. A good size for a heliotrope was found to be 9 inches, capable of throwing a ray of light from 80 to 100 miles. He also employed the Ray tracé system in minor triangulations. The difference in length of one of the base-lines of 7·42 miles, measured in both directions, amounted to 2·386 inches.

The measuring-rods employed for determining the length of the base were compared 50 times with the standard iron rods, and

101 times with each other. The 3 feet vertical circles were employed for astronomical determinations. In 1836, Col. Everest employed two of the large 36 inches theodolites, as also two others each 18 inches in diameter. In measuring one of the old base-lines, it was found to be too short by 2·825 feet, an error due to an omission to take into account the expansion and contraction of the steel chains which had been used.

The difference in the length of the Dehra-Doon base-line due to two measurements amounted to 7·2 inches; Col. Everest determined the arc of amplitude from Kalianpur to Dumargidda to be 6 degrees 3 minutes 35·9 seconds, and from Kalina to Kalianpur to be 5 degrees 23 minutes 37 seconds. Other important base-lines were also measured, and verified by calculation, with a difference of 4·296 inches.

Col. Everest's great arc-series extended over an area of 56,997 square miles, and cost £89,883. This great surveyor retired in 1843, and died in 1866. He was the inventor of that beautiful type of theodolite which still bears his name, an instrument which, from its lightness, compactness, and efficiency, recommends itself for use in all climates and in countries not very mountainous.

This great survey was continued from 1843 to 1861 by Sir A. Waugh, and he added 8,000 miles to the Indian triangulation. General Walker succeeded Sir A. Waugh, and in 13 years completed an additional 5,500 miles of triangulation, occupying 55 azimuth-stations and determining 89 astronomical positions. The sides of the triangle employed were from 15 to 16 miles in length, and on various occasions towers of masonry were erected 50 feet high. Heliotrope signals were employed at the stations during the day, and argand lamps during the night. The amplitude of the great Indian arc amounted to 23 degrees 49 minutes 23·54 seconds; but it is believed that the local attraction of the Himalayan mountains, etc., affected the latitude- and azimuth-determinations. It is, however, a very curious circumstance that when the calculated effects of such attractive forces were applied, there still existed a slight discrepancy in the final results, the origin of which has not yet been fully and satisfactorily ascertained.

General Walker, the late Director of the Indian Geodetic Survey, considered "that the effect of the attraction of mountain-masses on the plumb-line, which may be very great in the vicinity of mountains, will be reduced at a distance in greater proportion

than is assigned by the law of gravitation, as it has been hitherto applied; [this] because of the deficiency in density of the strata under the mountains, which has not been recognized." He is also of opinion that "as yet theoretical speculations have thrown little light upon the subject, as influencing the question of mountain attraction of the plumb-line, and that the pendulum-observations made in India show an excess of density under the sea-level." This latter deduction is confirmed by the pendulum-investigations of variations of density conducted underground by Sterneck.

In 1871, Messrs. Troughton and Simms, London, constructed at the request of the Indian Government, and under the superintendence of Col. Strange (then technical inspector of the Indian survey-instruments) a new theodolite, the horizontal circle of which was 36 inches in diameter. It was finely and beautifully divided, and the graduations of the horizontal circle were read by five powerful micrometer-microscopes to 1 second of arc, and by the micrometer-head, $\frac{1}{10}$ of that space could easily be read, or 0·1 second; but the instrument has since been altered to read to 0·5 of a second and by estimating the tenths as before, the lowest or finest reading becomes 0·05 second. The telescope has a great focal length with a large object-glass. Taken all together, this instrument is the best and finest ever constructed, and is intended to measure the angles between the sides of the larger triangles from the principal stations. It was, however, a very heavy instrument, and difficult to transport from one station to another in high mountain-regions. This instrument is shewn in Fig. 6: it is understood that it is now in the possession of the Government of the Cape of Good Hope.

Extra large and powerful spirit-levels of a special class were and are still employed upon this survey. A very careful system of levelling-operations is carried on, and by this means a large number of altitudes have been accurately determined.

The United States of North America Coast and Geodetic Survey seems to have been commenced about 1807; but a more general and properly organized system was introduced in 1821. In some of the geodetic operations, Borden employed theodolites with circles 12 inches in diameter. In 1867, from the measurement of six separate arcs, it was found that in north latitude 43 degrees and in west longitude 70 degrees 20 minutes, the length of a degree was equal to 111,096 metres, or 57,000·5 toises. The

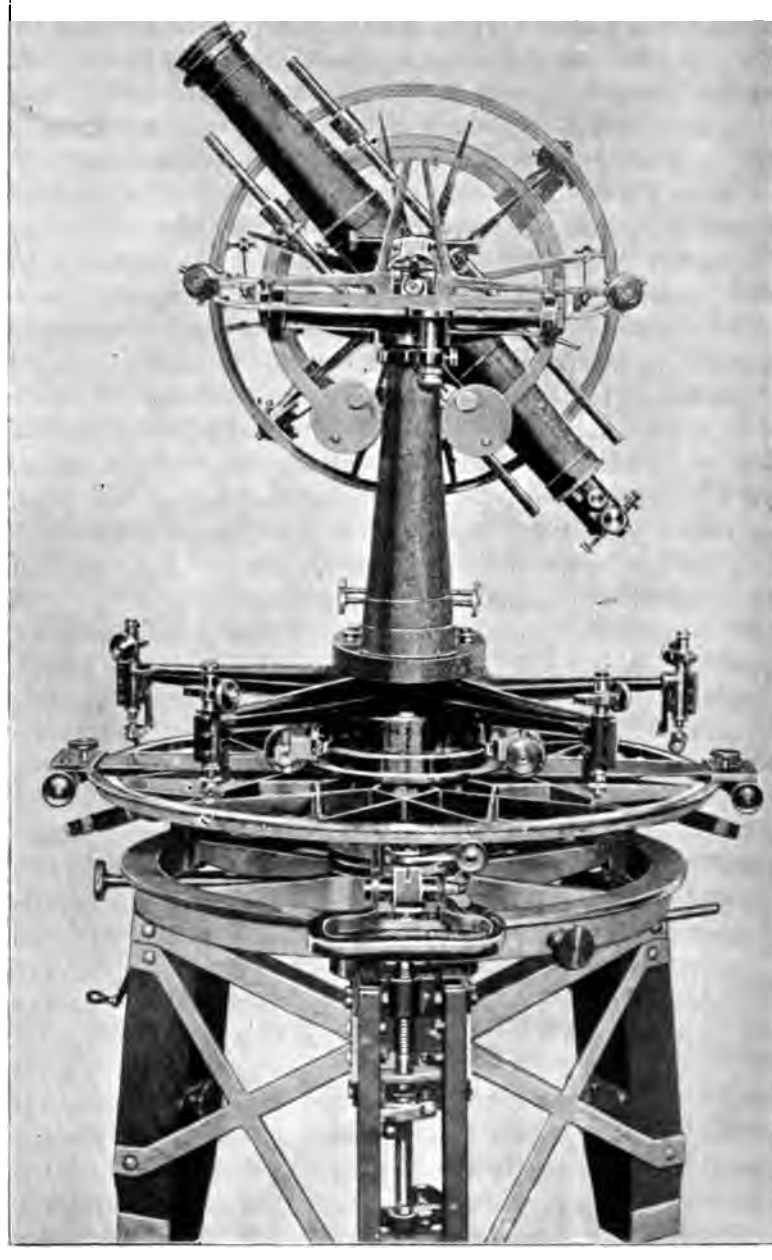


FIG. 6.—THE GREAT 36 INCHES THEODOLITE OF THE INDIAN GEODETIC SURVEY, 1871.

Pamlico-Chesapeake arc of 4 degrees 31 minutes 30 seconds was determined in 1876, from a network of triangles, formed from 6 base-lines and 14 astronomical stations, and it was found that the total error which resulted, probably due to local deflection, did not exceed 3·5 seconds of arc. The length of a degree of the meridian in north latitude 37 degrees 16 minutes, and west longitude 76 degrees 8 minutes, was found to be equal to 56,999 toises.

The results obtained by the various nations which have carried out surveys of the class under discussion, demonstrate clearly that the degree of accuracy to be obtained in a trigonometrical survey depends upon the precision with which the measurements of the primary base-lines and angles involved are carried out, as also upon the fineness of the instruments and the delicate mathematical processes applied to reduce and also to adjust such small, but, nevertheless, injurious discrepancies as may have unavoidably introduced themselves into the work during the process of observing. For these reasons, each country concurring has, in a sense, systematically competed in endeavouring to improve the instruments and processes applied to geodesy, some of the results of which we may trace in the remaining portion of this paper.

In 1834, the United States Geodetic Commission measured a base-line at Fire Island, on the southern side of Long Island, equal to 5·415 miles in length; and, in 1844, a second base-line was measured in Attleboro and Sharon, Massachusetts; as also a third base-line near the village of Epping, Columbia, Washington County, Maine, in 1857. The distance between Fire Island and the Massachusetts base-line taken along the axial line of triangulation, amounted to 230 miles, and that between the Massachusetts and the Epping base-lines amounted to 295 miles. An exceedingly high degree of accuracy was obtained in these operations, for the actual length of the Fire Island base differed only by 2·75 inches from the length which was recalculated from the other two bases.

The geodetic office authorities at Washington have given great attention to the construction of improved base-line measuring-instruments, some of which are considered to be almost perfect. There is attached to the Washington geodetic department a mathematical workshop, in which new angular instruments are constructed and old ones modified and repaired. Such a workshop was also, it is believed, once attached to the Indian geodetic survey.

For the final and principal measurements of base-lines, a measuring-instrument has been constructed of three metal bars; the two exterior ones being of steel, and the middle one, which is the shortest, of zinc. The end of one of the steel bars is placed in contact and square with one of the ends of the zinc bar, both being rivetted together. The other end of the steel bar is free and projects some distance beyond that of the zinc bar, being free to expand or contract. The second steel bar is placed upon the opposite side, but in contact with the zinc bar, their opposite ends being squared and rivetted together as in the former case. The opposite end of the second steel bar projects beyond the end of the steel bar first rivetted. This arrangement is believed to form a compensating metallic measuring-instrument almost, or at least approximately perfect. Mudge's contact-slide attachment, in an improved form, makes part of the instrument.

This particular construction is considered to be free from change of length, no matter what difference of temperature may be experienced. Such a condition seems to be obtained more or less perfectly by forming cross-sections of the steel and zinc bars in such a manner that they should be inversely proportionate to the specific heat of the metals. In deciding upon the thickness of the bars, the difference in the conductivity of heat is particularly taken into account. However, it is somewhat difficult to obtain a line-measuring instrument such as would be capable of fulfilling every proposed condition, especially when it is considered, in the case of metal bars, that it is highly probable that a difference of homogeneity in the particles of the metallic mass would exist. Such a condition would, as it appears to the writer, cause unequal expansive rates for different parts of the metallic measuring-bars. It is, therefore, doubtful whether any combined mechanical construction of this class could be made to retain absolute stability of length under all conditions. The North American engineers have, however, gone a long way in combining theoretical and practical principles, and in obtaining instruments capable of yielding high class results.

It has been previously noticed that various kinds of measuring-instruments for determining the length of base-lines have been devised, employed, and some of them abandoned from time to time. Still there are persons of authority who consider that compensating or standard steel chains are capable of giving good results.

No doubt these form a very convenient instrument, offering great facility in handling, and as previous practice indicates, capable of good work for preliminary determinations of the length of secondary base-lines when properly manipulated.

As a substitute for steel chains, steel tapes 101·01 metres in length by 6·34 millimetres wide by 0·47 millimetres thick, have been tried on some of the base-lines of the United States Coast and Geodetic Survey. When in use, such a tape is placed upon temporary wooden levelling-stands, and stretched straight by applying a weight at each end of about 25 pounds, thermometers being also attached to detect the difference of temperature. After various experiments and comparisons of steel tapes with an ice bar measuring adjusting-apparatus of standard length, the conclusion has been arrived at that, for such temperatures as are likely to be experienced in the use of such a tape-measure, the probable error in its absolute length would not on the average exceed ±0·05 millimetre.

The Holton base-line, 5,500 metres in length, was measured with a steel tape of the kind indicated, and the total error is reported to have been estimated at no more than ± 3·68 millimetres. The error in the Alban base-line, 3,870·512 metres in length, amounted to 3·10 millimetres. The mode of applying this class of measuring-instrument for determining absolute measure of length is undoubtedly susceptible of further improvement.

An arc of the meridian in the United States from north latitude 41 degrees 18 minutes to north latitude 44 degrees 40 minutes was measured with a resulting probable error of 1·30 millimetres.

The Dauphine base-line, 10,661·8376 metres in length, had a probable error of ± 0·026 metre. It was estimated that in measuring the Edisto Island base-line, 10,721·4321 metres in length, a probable error of ± 0·0256 metre existed. Other measured base-lines gave probable errors of ± 0·0127 and 0·0167 metre, proving that the metallic compensating measuring instruments employed and the mode of using them are very reliable.

The theodolites generally employed on the United States geodetic survey do not exceed 12 inches in diameter.

The geodetic work carried on in Spain has been of the most refined and efficient class, and the results obtained are excellent. The general plan initiated is similar to that followed in the Indian

trigonometrical survey. In Italy and Sweden, good geodetic work has also been done.

The boundary-line between the possessions of Great Britain and the territory of the United States was defined by a mixed commission between 1872 and 1876. The astronomical stations (41 in number) were 20 miles apart, the intermediate distances being traced by tangent-lines from one to the other, and after correcting for azimuth and other errors the calculated off-sets—from 1 to 3 miles in length, were measured, determining other points in the latitude-circle. The line thus traced proved to be an irregular curve only approximately coincident with the astronomical parallel. The discrepancies existing between the astronomical and geodetic determination of relative positions on the earth's surface have been deduced from the measurement of certain arcs of the meridian; and after general corrections had been made such difference could only be referred to the variation in the density of the earth, the mean value of which had been attempted to be determined. The deflection of the plumb-line from the vertical has amounted to 20 seconds, 30 seconds and as high as 40 seconds with variations, its cause being based upon the established law of Newton. The mixed commission of British and North Americans, previously referred to, found an error in azimuth of 14 seconds with variations all along the line traversed. At one of the stations the deflection was 7·28 seconds, or a difference of 738 feet from a point in the true parallel which it was required to trace.

Apart from the practical importance of such results, bearing upon future operations, the principles involved produce sufficient evidence to prove that instruments freely suspended upon a centre, as in the case of a magnetic needle, would be subject to the same conditions as a plumb-line and consequently liable to be deflected from the true direction, the amount of which would depend upon their position, in reference to the difference of the physical condition of parts of the earth's crust.

Fig. 7 shews a theodolite with 18 inches divided circles, constructed by Messrs. Troughton and Simms for the Cape of Good Hope Geodetic Survey. It has three micrometrical microscopes attached reading the circle to 1 second of arc, and by estimation, $\frac{1}{10}$ of that quantity may be obtained from the divisions on the micrometrical screw-head or circle. In measuring 100 angles with this instrument at the Cape, it was estimated that the

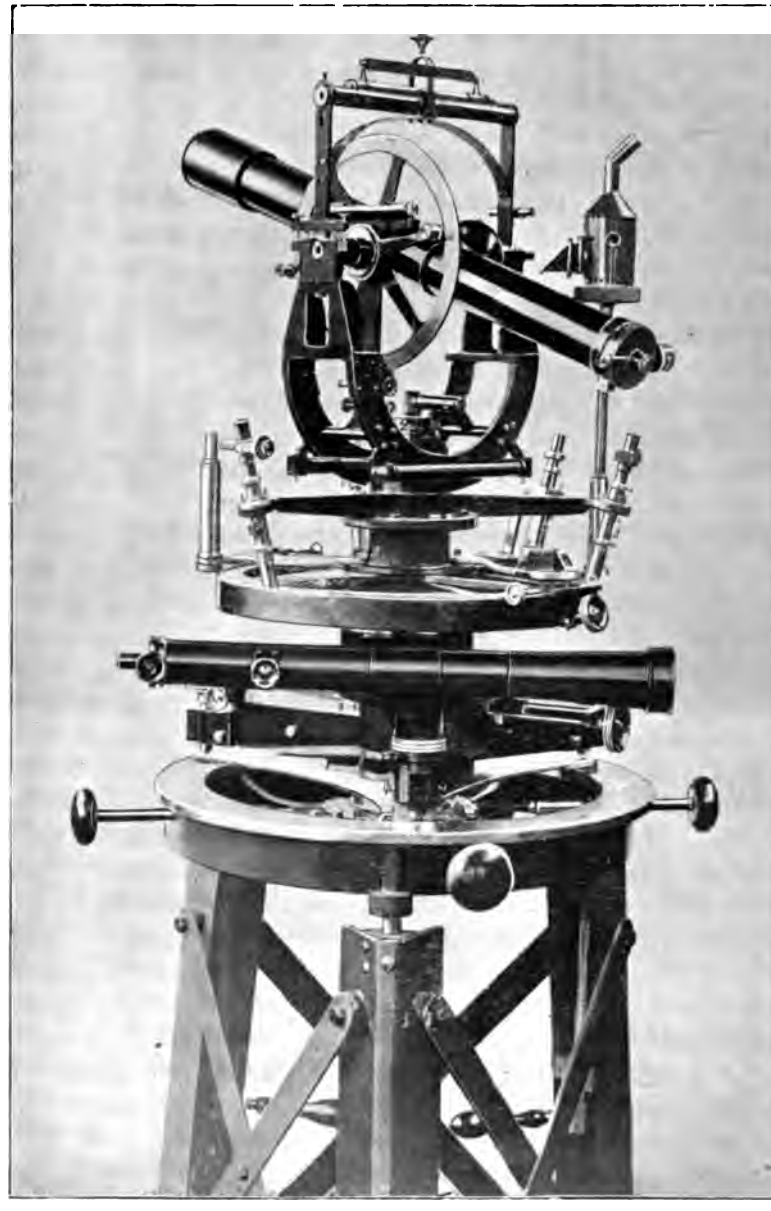


FIG. 7.—THE 18 INCHES THEODOLITE OF THE CAPE OF GOOD HOPE GEODETIC SURVEY.

probable error in any single angle did not exceed ± 0·49 second. For some reason, Dr. Gill, the astronomer at the Cape of Good Hope, seems to have preferred a class of theodolite made by Mr. Repsold of Hamburg, with 10 inches circles; and it is stated that in measuring 134 angles by that instrument the probable error on any single angle did not exceed ± 0·33 second. However, other observers at the Cape found that from the use of this class of instrument the probable error amounted to ± 0·424 second, differing from that of the 18 inches instrument by 0·066 second, and if this quantity could be established as a constant, from a long series of observed angles, it would be of little significance.

It would, however, seem that preference has been given to the use of the 10 inches Repsold theodolite, more from its portability one would suppose, than from any other well-founded reasons. Dr. Gill considers that there existed a continued source of error due to lateral refraction which, he says, nullifies the greater accuracy which might possibly be obtained with an instrument of greater power. But it would seem that this theory should be accepted in a qualified sense, as applying to particular and confined localities such as flat arid plains existing in the torrid zone, and where there is a concentrated heat accumulated in the subsoil, rather than to mountain-regions of great elevation and in cold climates where the air is more rarefied and free from Dr. Gill's lateral refraction; he also thinks that by arranging the triangulation with shorter sides, better results would be obtained: naturally this would prove a convenience to suit the use of a 10 inches instead of an 18 or 36 inches instrument. It appears that the mirage encountered on the flat and arid plains near Vryburg, in British Bechuanaland and other places in Cape Colony, proved detrimental to telescopic observations, and it has been estimated that the probable error on a single observed angle would amount to ± 1·41 seconds. Consequently, to avoid the effects of Dr. Gill's lateral refraction as much as possible, smaller instruments and shorter sides for the triangles have been employed than those adopted in India and other countries.

The 18 inches Troughton instrument used in Cape Colony, which is a very fine one, has a telescope of 22·5 inches focal length, and an aperture of 3 inches. The lower, or check-telescope, has a focal length of 24 inches and an aperture of 2·5 inches, and is attached to, and revolves horizontally by means of a cylindrical

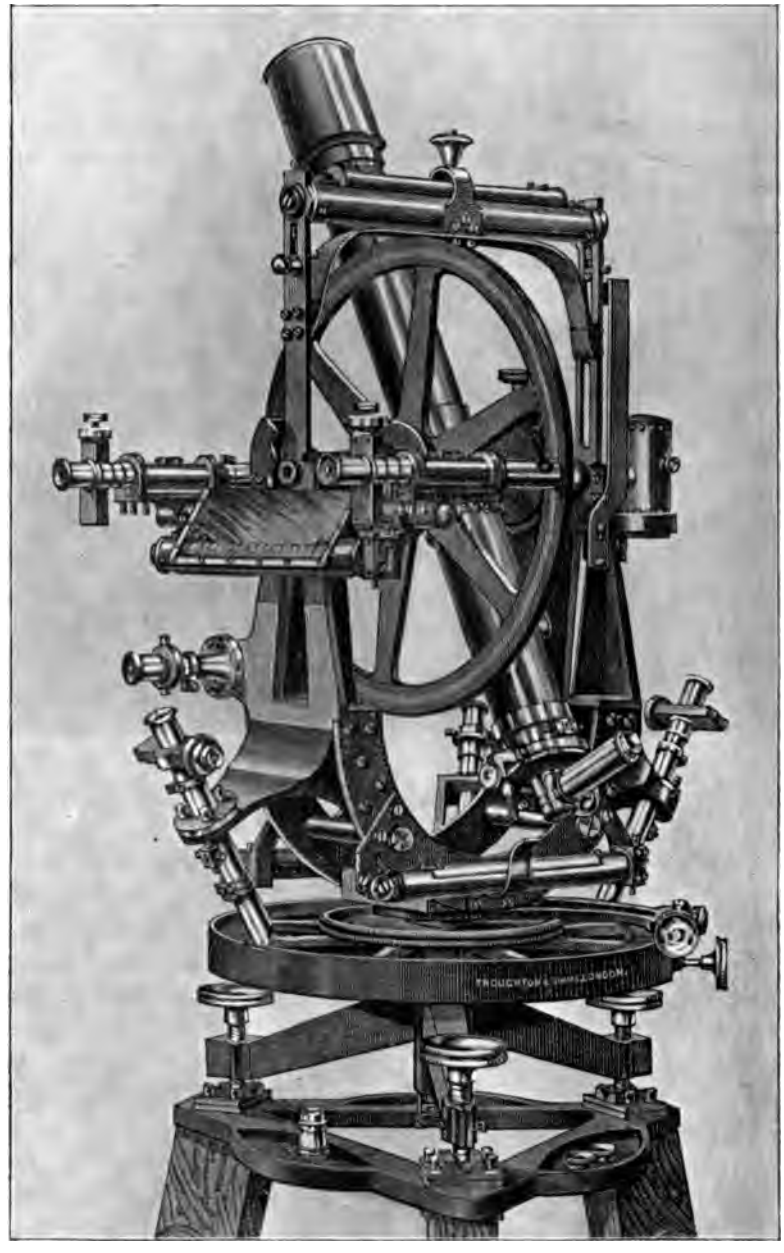


FIG. 8.— A 12 INCHES THEODOLITE FOR GEODETIC SURVEYS.

collar on the side of the vertical axis under the graduated circle. This instrument was sent to its maker for alteration in 1895, and was exhibited at the International Geographical Congress in London.

Fig. 8 is an instrument made by Messrs. Troughton and Simms, with 12 inches divided circles, and has attached three micrometer-microscopes, reading the horizontal circle to 1 second of arc: it is a model instrument, with great optical power, and is sufficient for all geodetic operations when the sides of the triangles are not excessive. Its reading qualities may be improved by attaching a vernier to the divided micrometer-head or circle, for reading fractions of a second instead of estimating such small quantities. It is also an admirable instrument for use in place of a zenith-telescope, for latitude and other determinations by the Talcotte method.

Fig. 9 shews an excellent instrument made by the same firm to the order of the writer, with 8 inches divided circles. The horizontal circle is read by three verniers to 5 seconds of arc. It has two vertical circles, one on each side of the telescope, reading to 10 and 5 seconds of arc, and they are very useful in giving four separate readings in altitude for each separate observation. Each circle has an independent set of clamps and tangent-screw apparatus: this is a valuable arrangement, each set being used in succession when observations are being made upon quick-moving celestial objects near the meridian, namely, when the left-hand tangent screw is up and ceases to act, and there is no time to reverse it, the right-hand one is immediately brought into use, and so on alternately. This instrument has been used by the writer in mountain-regions and found to be very effective. If longer lines are required, then the angles are observed by the instrument shewn in Fig. 7. The long diagonal eye-piece, attached to the instruments represented by Figs. 7 and 8, is exceedingly useful when high vertical angles have to be measured, and, consequently either of those instruments is admirably adapted to the Talcotte process, previously noted. The spirit-levels attached to both instruments are long and sensitive: each division on the levels of the instrument in Fig. 8 represents 1 second of arc, and those on Fig. 9 are 5 seconds apart.

The method of finding distances and altitudes by stadia and telemeter processes have found much favour in various countries,

especially in the United States of North America and Italy. Some authorities have suggested that micrometric eye-pieces should be attached to the telescope of instruments with one or

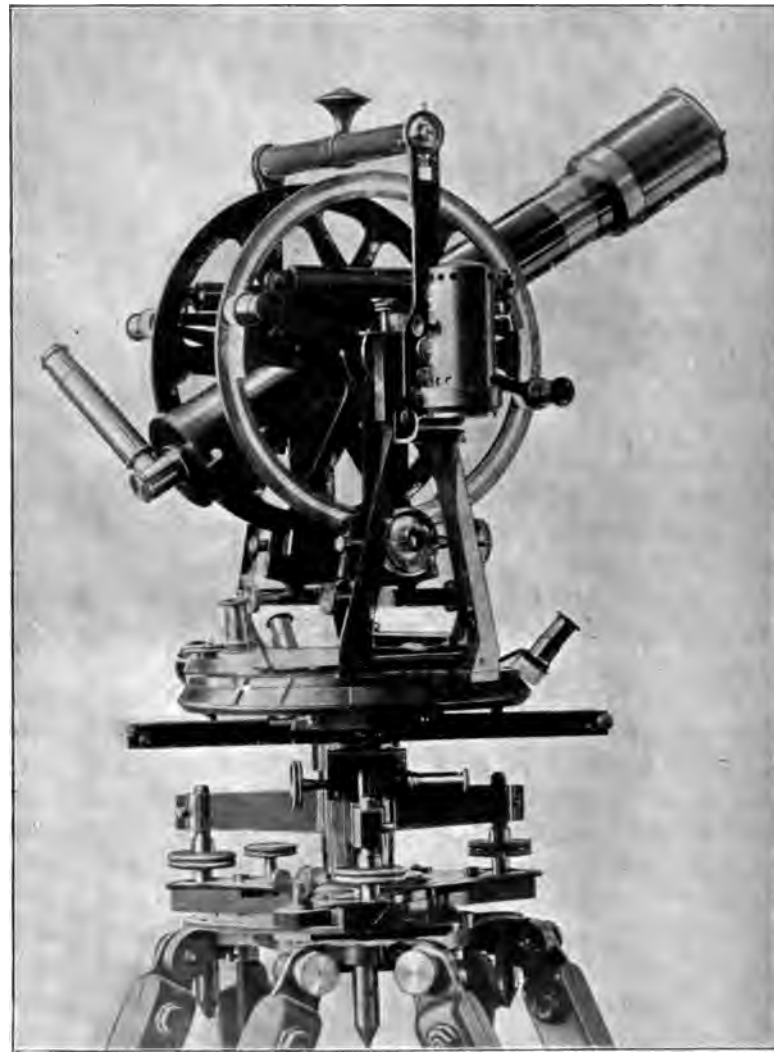


FIG 9.—AN 8 INCHES THEODOLITE FOR GENERAL SURVEYS.

three horizontal wires placed in the focus and independent of the moveable micrometer-wires; but it has been stated by others that this plan of finding distances has not produced good results in

India, arising from the fact, so it is stated, that the movable frame carrying the horizontal wires is parallel to and at some distance from the fixed wires in the focus of the telescope, and consequently, not in the same vertical plane; nevertheless, North Americans say that, in their instruments, the three parallel hairs when required to find distances, or the micrometric wires, are placed upon the same plane as the permanent diaphragm-wires, thus obviating the discrepancy complained of and produced by the old construction.

A new system of finding distances—said by the North Americans to be a hundred years old—has been invented and practised in India to a considerable extent and with great success by Col. Tanner, Indian Staff Officer. He says that several delicate and expensive instruments were already at hand with micrometric eye-pieces attached, by which, when used in conjunction with bars or base-rods of known length, horizontal distances could be measured more or less near to the truth: but such instruments were too complicated and delicate in their parts to bear the rough treatment that they might receive at the hands of the native establishments to which he had mostly to look when conducting the Himalayan survey. Besides this drawback he did not find micrometrical instruments capable of yielding sufficiently accurate results for the purpose of obtaining traverse distances within the prescribed error admissible for work on the large scale of 56·7 inches to 1 mile, which was laid down for the more open parts of the country which came within his control. Col. Tanner then describes his bar-subtense process which consisted in setting up a wooden bar of a given length, horizontally, at any distance and then observing the intervening angle, frequently repeated, and calculating the distance by a simple trigonometrical rule. Each end of the bar-subtense, or artificial portable base-line, was mounted with a circular disc, 12 inches in diameter, to the centre-line of which the vertical wire of the telescope was directed. Col. Tanner states that under favourable conditions of light and atmosphere, a skilled observer could obtain a 3 miles distance to within 6 feet of error; also that a 10 feet horizontal bar would give a good result to 1·5 miles. He seems to have experimented upon bars of different lengths down to a 2 feet Gunter scale, blackened at the ends with 2 inches discs, and that he obtained good results for a 20 chains distance. Col. Tanner gives the following example of calculation:—

Bar, 20 feet or 30·3 links	Log	= 1·48144
Observed angle, 20 minutes 11·9 seconds ...	Log cosec.	= 2·23122
Distance is 51·601 chains	Log	= 3·71266

It is evident that this plan would be facilitated by calculating a table of distances corresponding to such angles as would be likely to be employed.

Col. Tanner says that "it is an error to suppose that a distance cannot be found correctly because the angles are small, and the relation of the sides of the triangles do not approach that of an equilateral triangle; and further that the results to be obtained by this method are superior to any other, short of that of a trigonometrical survey."

However, the writer considers that when the angles are exceedingly small, and the distance to be determined very great, a bar-subtense of 20 feet, or even 25 metres in length, would be inadequate. Taking for example an angle of 5 minutes, with a subtense base-line of 25 metres, we should have a distance of 17,188·7362 metres, and for an angle of 5 minutes 1 second 17,131·6338 metres, giving a difference in distance due to 1 second of angle, of 57·1024 metres. Such a difference is too great to admit of the employment of this system, for such long distances and for very accurate work, without adopting a longer bar-subtense, or portable base-line. When an exact survey is required, and an open or nearly level field or camp can be found, a short base-line may be accurately measured in place of, and to be used in the same manner as the bar-subtense, say, for example 300, 500 or 800 metres in length, or other convenient measure. Taking 800 metres for such a base-line, and employing angles of 2 degrees 31 minutes, and 2 degrees 31 minutes 1 second, the corresponding distances would amount to 18,219·0807 and 18,217·0705 metres respectively. The difference in length due to the excess of 1 second of angle is, therefore, 2·0102 metres, which divided by the first distance or 11·321 miles, gives a difference of 6·99 inches per mile. When, therefore, the length of the bar-subtense, or short base-line, and the angles to be observed have a reasonable and determined relation or proportion to the distance to be found, the case given proves that a very high degree of precision can be obtained by this ingenious method, such as is not possible by the best system of direct ordinary chain-measuring or stadia determina-

tions. This is, it is true, an excessive distance seldom entering into common practice; but on shorter distances and with finely divided instruments better results would be obtained.

Some mathematicians and practical observers have, however, contended that the combined personal and instrumental errors arising from and due to the process of bisecting a fine distant mark or perpendicular line on a target would be as much as ± 1 minute 21 seconds; but high optical quality giving great penetrating power in the telescope, combined with fine micrometrical reading of the circles of the instrument, or in the focus of the telescope, as also various measurements of the same angle, employing properly constructed and illuminated bar-subtense targets with a definite bisection of the centre-lines, would tend to reduce such errors to a minimum and, probably, in some special cases eliminate them altogether. The bar-subtense method would be exceedingly useful for night operations by using a target with discs at each end of the base-line, constructed so as to be illuminated by electric process.

As previously indicated, Col. Tanner introduced this system into India, and in 1891, he read a paper upon it at the Geographical Section of the British Association at Cardiff, on August 21, as also before the Royal Geographical Society, London, in November of the same year. The present writer explained this system in his paper upon geodetic surveying read in the Civil Engineering Section of the International Congress of Engineers in Chicago in 1893. Since that period, however, it has been claimed by Mr. Urrutio of Guatemala, and some North Americans believe that he is the inventor. However, if it is a recent invention at all, it is undoubtedly due to Colonel Tanner. Nevertheless, we know that Gascoigne invented a micrometrical microscope for measuring distances in 1640.

Some North American engineers have attempted to prove in their scientific journals that the distant line to be measured or determined by the subtense process is a horizontal one, whether the subtense-base is observed upon level or elevated ground; others, including the writer, have, however, opposed this idea and demonstrated that the observed horizontal angles obtained from the bar-subtense in elevated regions, give directly the hypothenuse or inclined line of a vertical right angled triangle and not its base, without further reduction by a simple trigonometrical rule.

It is evident that to perform this surveying operation with extreme precision, over great distances, a very large instrument reading to fractions of a second would be required, as also great optical power; but to obviate this, and the great expense, Messrs. Troughton & Simms have introduced an instrument consisting chiefly of a powerful telescope mounted upon a strong and firm stand with simple horizontal and vertical motions. The telescope has a focal length of 23 inches and an object-glass 2½ inches in diameter, with a micrometric eye-piece attached. The micrometric head or circle is fixed to a hundred-thread screw, each division on the head being equal in value to one second of arc, and it is easy to estimate to 0·1 second. The fineness of the reading depends upon the size of and number of divisions upon the micrometer-head; but if a vernier were to be attached small angles could be read down to 0·01 second or probably less. This firm has constructed instruments of the same class for the Indian survey, and for the Argentine and Chilian Governments for use in the work necessary to determine the Andine boundary-line between the two republics.

The method of finding distances by vertical angles sub-tended by a perpendicular graduated stadia rod of a given length similar to a levelling-staff is much employed in North America and other countries, and it has been affirmed that on distances of from 800 to 1,000 feet, errors varying from 1 in 650 to 1 in 800 have arisen, and that on distances from 500 to 600 feet the error has been at the rate of 0·03 to 0·04 foot; but considering the comparatively coarse divided instruments employed in the United States, reading generally to ½ minute of arc, and with low optical power, it is difficult to reconcile the statement that on a distance of 3,800 feet, determined in a very hilly country in the United States, the error on the total length did not amount to more than 0·13 foot!

It has been proposed to obtain topographical features of a mountainous country by photographic observations taken instantaneously from a captive balloon, steadied in the air by guide-ropes; but to prevent much overlapping, confusion, and to enable the cartographers to fix the photographs together properly, it would be necessary to divide the country surveyed into sections, erecting well-defined station-marks which could be easily recognised when the surveyors require to shift the balloon from the centre of one section to that of another.

A well-planned scheme of this kind would aid the faithful delineation of topographical features to a considerable extent, and produce more correct results than could be obtained by the ordinary methods.

For pioneering expedition in difficult elevated countries, the camera is a very important instrument, saving an enormous amount of time in obtaining faithful sketches. In this sense every engineer and others engaged in foreign work would do well to become expert in photography. Small cameras are now attached to a certain class of theodolite, and are reputed to be of great service as an auxiliary means for determining the topographical features of the lines of survey; but in such instruments the telescope is fixed concentrically, and for this reason it may not be preferred. Further on in this paper the writer proposes to indicate a remedy for the apparent error introduced when angles are observed with a telescope revolving round the circumference, instead of being mounted over the centre of a circle.

The Schlichter apparatus for geographical topographical data by photography exhibited at the International Geographical Congress, London, 1895, is intended to be used for such purposes where the distance of objects is not more than 500 feet. The Stewart "panoramo" is also intended to be used for surveying by the aid of photography.

In carrying out topographical work in elevated and precipitous mountain-regions in foreign countries, as in the Andes, it is customary to determine many level points and distances from a single station, taking care at the same time, that the vertical distance between the contour-lines is sufficient to be well indicated upon the map.

Transit-theodolites from 7 to 7·5 inches in diameter are exceedingly useful, and sufficient for most ordinary land-surveying purposes. Greater efficiency would, however, be obtained in such instruments if micrometrical microscopes were always added, reading either to 5 seconds or 1 second of arc. In elevated regions, where the air is clear and steady, as is the case in South America, India and other similar regions, such instruments would be sufficient to observe the angles of a secondary series of triangles in a trigonometrical survey. Transit-theodolites, with 5 and 6

inches circles, are now commonly constructed to read to either 10 or 5 seconds by special means. For exploring parties in unknown regions, 4 and 5 inches instruments made of aluminium would be sufficient for such work, and for taking simple astronomical observations for latitude, longitude, azimuth and time purposes. A 3·5 inches instrument is also a useful size for individual private work of no great extent.

The slight discrepancies which frequently occur in determining the angles and sides of oblique-angled triangles in a series of primary and secondary triangulations render it necessary to take into consideration the spherical excess, as also a particular corrective condition derived from the principle of least squares.

The geodetic practice of the nations is of the greatest practical utility and scientific interest, especially as examples for new countries, such as the South American republics and others in which, as yet, trigonometrical operations have not been systematically initiated.

The Argentine Republic, running, as it does, from the frontier of Bolivia to south latitude 55 degrees 3 minutes 30 seconds, embracing an arc of the meridian of 33 degrees 3 minutes 30 seconds, offers probably more advantages for ascertaining the length of a degree of the meridian in the whole extension indicated than any other country. There is still, therefore, open to men of science in general and geographers in particular a vast field for geodetic operations and deductions.

Perhaps it may not be superfluous to note that some good points requisite in a theodolite of precision, for geodetic and also for general surveying-operations, consist in lightness of construction, rigidity, stability of working parts, accurate and equidistant divisions of the circle and verniers, properly constructed and nicely adjusted micrometer-microscopes, minimum eccentricity, and great penetrating power of telescope, the optical axis coinciding with the centre of the divided circle. Under no conditions should a dead or counterpoise weight be attached to one side of the vertical circle-axis, as is sometimes the case, with the object of balancing the vertical circle and clamp and tangent-screw apparatus on the opposite side. If such a balance be necessary, at all, it would be far preferable to place a second vertical circle at the opposite side with double clamp and tangent apparatus, very long and nicely adjusted levels, etc. As previously noted, the second clamp

and tangent apparatus is exceedingly useful for bringing into use at the moment when the first tangent ceases to act on the circle, and the observation is being made upon a quickly-moving object near the meridian.

The use of mathematical tables are closely connected with this subject, namely, logarithms of common numbers, and sines, cosines, etc. Of these tables, there are a large number; but the larger, more valuable, accurate, and minutely calculated and important works, such as Napier, 1614; Briggs, 1624; Vlacq, 1633; Sherwin, 1704; Gardiner, 1742; Taylor, 1792; contain the sines, cosines, etc., to every second throughout. Vega's *Thesaurus Logarithmorum*, 1797, is calculated to 10 decimal places. All of these are very scarce. Those of more recent date are Callet, 1797; Hutton, 1801; Shortredge, 1849; Vega, 1861; and Babbage, 1872. The greatest masterpiece of modern work of this class known to the writer, is the work published by General Shortredge and Major Hannington in 1873. This book contains logarithmic sines, cosines, tangents, etc., calculated to every second throughout the circle extending to 497 pages, and is exceedingly valuable for reductions and calculations of observations in high-class surveying, astronomy, etc. Babbage says that he consulted an extensive manuscript of logarithmic tables preserved in the Paris astronomical observatory, and he calls it "a treasure of calculations." The tables of Dupuis, 1891, and Chambers are useful for students.

We have now arrived at a branch of this subject which is of the greatest importance, namely, mining or subterranean surveying for the formation of maps, plans and sections of mines. It is of great value when it becomes necessary to employ it for determining the position, direction and length of galleries or underground tunnels which may have to be constructed under varying conditions and circumstances, for the economic working of mines and the extraction of minerals.

Sometimes such tunnels have to be set out and constructed from two opposite points, and then the art of surveying and the ingenuity with which it is conducted are rigidly put to the test. Naturally the accuracy of the meeting-points of the axial line of the underground tunnel would depend in a high degree upon the class

of the angular and line measuring-instruments adopted, as well as the system employed, and the amount of care given to the whole of the operations involved.

There are many good practical examples on record, one of which may be cited. To reduce the expense of drainage and extraction of the coal from the Brayton Domain colliery, a drift or tunnel, 3,567 feet in length was commenced in 1889, from two opposite ends. A transit-theodolite, 6 inches in diameter, reading to 20 seconds, was employed; the work occupied 639 days, and the meeting-point of the two sections could not be appreciated. Sights were taken to a plumb-line placed before a screen and illuminated from behind, the distance being measured by a 100 links chain.

In England, Thomas Fenwick, a very practical mine-surveyor of Dipton, in the County of Durham, was the first, as far as the writer is aware, to introduce, in 1801, a complete system of underground surveying, employing the miner's dial; and, in 1804, he advocated the plan of observing horizontal angles formed by the tortuous roads in mines by employing the graduated circle of a circumferentor, probably with coarse verniers, which plan he termed "fast needle," that is, the magnetic needle was not used after the first bearing had been observed by it. Considered as a general system of mine-surveying by the miner's dial, the book of Fenwick has not been, neither will it ever be superseded. His fast-needle process is also the base of the theodolite practice of to-day. However, at that period the miner's dial or circumferentor, was very coarse and imperfect in construction, and when it was necessary to connect underground workings with the surface, the magnetic needle had to be employed.

In 1845, Budge published a very useful work upon this subject, and he continued to recommend the use of the miner's dial.

Butler Williams, in 1842, published in his *Practical Geodesy* an excellent chapter upon subterranean surveying, advocating the use of the theodolite in a modified form, and employing three tripod-stands and lamps, interchanged at each alternate station with a theodolite; but unfortunately, although effective, this plan was not generally adopted.

Rikard followed in 1859 with a treatise on mine-surveying by the old plan of the magnetic needle.

The writer published a practical treatise upon mine-surveying, etc., in 1863, introducing a system of conducting all such opera-

tions with a specially constructed miner's transit-theodolite, which he believes he had in use prior to 1859; but introduced by him in 1863. The work referred to suggests that for convenience the first line in any underground survey, generally connected with a shaft or shafts, should be made an artificial meridian or base-line throughout the plan, to which all the other lines in the survey should be referred, after the horizontal angles had been reduced to plotting angles, to be transferred to the plan by means of a circular protractor or co-ordinate system. That work was used as a class-examining book on mine-surveying in the City and Guilds of London Institute, and in others, and although it is out of print it is still in great demand in Great Britain and the United States of North America. In that treatise, a plan is exhibited for connecting the first line in an underground tunnel or drift to the surface by sighting up a shaft with the telescope of a transit-theodolite; but the writer found the plan laborious, inconvenient and difficult to carry out under all circumstances. At the same time, for shallow dry pits, satisfactory results could be obtained when the operation was performed at night, and if the wire stretched across the mouth of the shaft or other object sighted were illuminated. For comparatively shallow pits, he adopted the more direct mode of suspending two chains down the shaft, and by this means obtained good results. The writer cannot see any reason why chains could not be constructed to be suspended down shafts of considerable or, in fact, any depth: the only question to be considered is the diameter of the steel wire to be used, which should diminish downwards, enabling the upper links to sustain the weight. The lower portion could be made of aluminium. This plan is simple and in the absence of an instrument to carry out Mr. Arthur Beanlands' plan would prove efficient.

The system of mine-surveying with the exclusive use of the theodolite and the co-ordinate mode of plotting the survey upon plans and maps by means of traverse tables, or tables of sines or cosines, introduced in the work of the writer was, and always will be useful and applicable in every mining district; as is well known in Great Britain and has been proved in North America, where, many years since, the methods recommended were adopted to a considerable extent, no matter whether underground drifts or tunnels were connected with the surface by means of chains sus-

pended down a shaft, by a transit-theodolite from the top of the shaft, or by means of a magnetic bearing. To attempt to propagate an opinion to the contrary, from mere motives of prejudice and inability to appreciate the merits of others, is as ridiculous as it is opposed to justice, experience and sound judgment.

After performing various scientific experiments with the view of determining a reliable and facile mode of connecting underground drifts or tunnels to the surface, Mr. Arthur Beanlands, the wellknown civil engineer of Durham, read in March and August of 1856, a very able paper before the North of England Institute of Mining and Mechanical Engineers, containing a system of performing this very important operation which we are now discussing.* This plan consisted in sighting down a shaft by means of a powerful telescope, bisecting two fine points previously placed at the bottom of a shaft and in the direction of the first line of the underground heading or tunnel. The telescope was then raised to the horizontal position, taking great care during this process that the instrument had not been disturbed in position, and the underground line was then set out at the surface by permanent marks, as compared to some other line previously fixed. Mr. Beanlands claims this plan as his own invention and, undoubtedly it is an exceedingly accurate and facile system—not to be superseded by any other means—which, if properly carried out, could never fail in its object. If it has not become general in Great Britain and other countries, it certainly should, and the plea of expense in the purchase of a proper transit-instrument, is not a sufficient excuse for incurring the risk inherent in the use of inferior instruments and bad practice.

Referring to the first principles upon which all surveying operations should be made to depend, and as a high standard of reference, nothing can exceed the chapters upon this subject published from pages 1 to 130 of the work upon *Civil Engineering*, in 1862, and in 1889, by the late Prof. John Macquorn Rankine.

An exceedingly useful, practical, original and able paper upon underground surveying is that written by the late Mr. W. F. Howard, in 1871.† It cannot be too highly recommended to the

* *Trans. N.E. Inst. M.E.*, 1855-6, vol. iv., pages 267 to 270.

† *Ibid.*, vol. xx., pages 19 to 47.

attention of persons engaged in mine-surveying; but especially to those requiring to enter upon such a study and practice.

In 1888, Mr. B. H. Brough published an useful little treatise, well adapted for teaching the elements of *Mine-surveying*, including a short description of some of the instruments employed, as, also, a notice of a few foreign and rare books referring to this subject.

In France and the United States of North America, theodolites are frequently constructed with an additional telescope, attached to the extreme end of the horizontal axis which carries the ordinary or central telescope and vertical circle. A perpendicular sight may then be taken by the second telescope. Occasionally, also, the Ys supporting the horizontal axis and telescope are bent forward at an angle, so that, when the telescope is turned over, a sight may be had down a vertical shaft. Another plan is to attach a second telescope parallel to the ordinary one, and in the same vertical plane, supporting it by distant pieces, so that when the first telescope is revolved the second one has a perpendicular position; but the writer considers that all such modes of construction are exceedingly awkward, unsightly, and unless handled in a very delicate manner the instrument would be liable to considerable vibration, rendering the work performed uncertain. The best transit theodolite, made in the United States and applied to mine-surveying, is that invented by Mr. Dunbar Scott, an American engineer.

The first notice known to the writer referring to a direct telescopic mode of connecting or reproducing a surface-line in a given direction in an underground tunnel is to be found in Mr. C. Bourns' *Principles and Practice of Engineering and Other Surveying*.* The method indicated by Mr. Bourns was employed in constructing the Box tunnel on the Great Western Railway. He says that "the shafts were so deep (some of them from 300 to 400 feet) that it was found that the plumb-lines would not answer the purpose, on account of oscillations caused by currents of air or otherwise. The following method was therefore resorted to: shafts 20 feet in diameter were sunk in the line; the centre-line at these shafts was fixed by a theodolite, or a transit-instrument, as the case might be; the mode of accomplishing this will be understood on reference to the following figure. The instrument being first set in the line, on the surface, at A or B, (Fig. 10), and a point fixed at the

* London, 1843, pages 249 and 250.

bottom of the tunnel by means of the vertical arc; and then another point was found in a similar manner from the other side; a short length of line was thus obtained which was carefully produced both ways to meet other portions worked from the adjacent shafts. These points and a line through them were tested at every length before the brickwork was put in. When a shaft is so deep that the range of the arc of a theodolite is insufficient to enable an observer to see to the bottom of a tunnel, a transit-instrument must be made use of instead." Fig. 10 is an enlarged diagram of that given by Mr. Bourns.

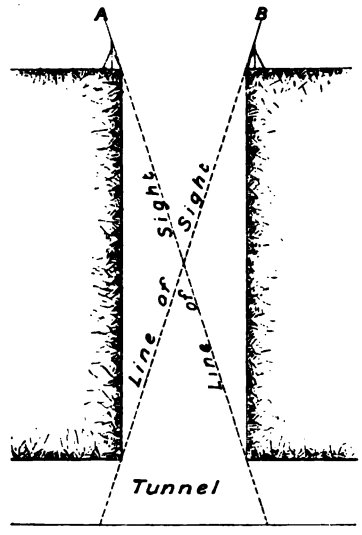


FIG. 10.—MR. J. C. BOURNS' METHOD OF PRODUCING A SURFACE-LINE IN A GIVEN DIRECTION UNDERGROUND FOR TUNNELLING PURPOSES, 1843.

The late Mr. F. W. Simms, in his *Practical Tunnelling*,* refers to the same plan; but he did not practice it in driving the Bletchley and Saltwood tunnels; in fact he was not favourably impressed with the facility or accuracy of the process. He commenced the works referred to, in 1840, and it is probable that he and others knew of the plan practiced by Mr. Bourns prior to that date, probably about 1837. Mr. Simms published his *Public Works of Great Britain* in 1838.

Before the Severn Tunnel was constructed, its length being 2 miles, a shaft was sunk on each side of the river and poles were erected on the surface to indicate the direction of the tunnel. To produce this surface-line belowground in the direction which the tunnel should take, a short base-line was first employed at the bottom of each shaft. A powerful transit instrument was placed over each shaft in succession, and the axial line or vertical wire in the focus of the telescope was directed to the point on the opposite side of the river. After a very fine bisection, the telescope was then turned to look down the shaft, and in this way the short base-line before mentioned was produced. After a short length of tunnel had been driven in the direction thus indicated, a

* London, 1844, pages 33 and 34.

fine wire 300 feet in length was fastened at the side of the shaft opposite to the direction of the tunnel, stretched along the part of the tunnel already driven, and tightened by a weight attached to it and suspended at the other end. A transverse movement was communicated to the wire by means of screws fixed in a specially formed apparatus, and the wire was thus made to coincide with the vertical hair of the transit-telescope. The direction of the tunnel was tested in this manner on various occasions. This was a very delicate operation, especially as so much depended upon it, for no more than 14 feet of wire at the bottom of the shaft could be seen through the telescope. However, owing to the great care and ingenuity of Mr. Richards, the engineer in charge of the works, the point where the tunnel met from the two opposite ends exhibited no difference either in direction or level. Very good work of a similar nature has also been done on the continent of Europe and in North America by employing a similar system.

Some 35 or 40 years ago, when the writer interested himself in performing surveying operations, he executed tunnels in iron-mines and coal-mines from opposite points, the base-line employed at the bottom of the shafts, on some occasions, upon which the whole survey hinged, being no more than 8·5 feet in length, and upon distances from 600 to 750 feet, the junction of the heading or tunnel could not be distinguished either in level or direction, proving that if the distance had been 20 times as long, similar results would have been obtained. The base-line of 8·5 feet, previously referred to, was set out in the bottom of the shaft by Mr. Beanlands' system, and it was continued by stretching a fine copper wire through the fixed points, at the bottom of the shaft, to form a longer base-line along a drift, made to connect the shaft with the tunnel which was driven in another direction.

In or about 1863-64, the writer designed a second theodolite of a particular type for underground, ordinary and high-class surface-surveying, and read a paper upon it in 1865;* but it was discovered that errors had been introduced into the construction, and for that and other reasons it was allowed to lapse until 1889. As the writer, however, still believed in the useful principle of the instrument, the original one was improved in that year. The writer did not consider it quite satisfactory, and ordered a new one to be made by Messrs. Troughton & Simms, introducing modi-

* *Transactions of the South Wales Institute of Engineers*, vol. iv., pages 133 to 145.

fications and improvements; and it was exhibited in the Argentine Mining and Metallurgical Section of the Columbian International Exhibition, Chicago, in 1893.

The judges of scientific instruments gave the highest award for the theodolite, finding its chief points of excellence to be:—

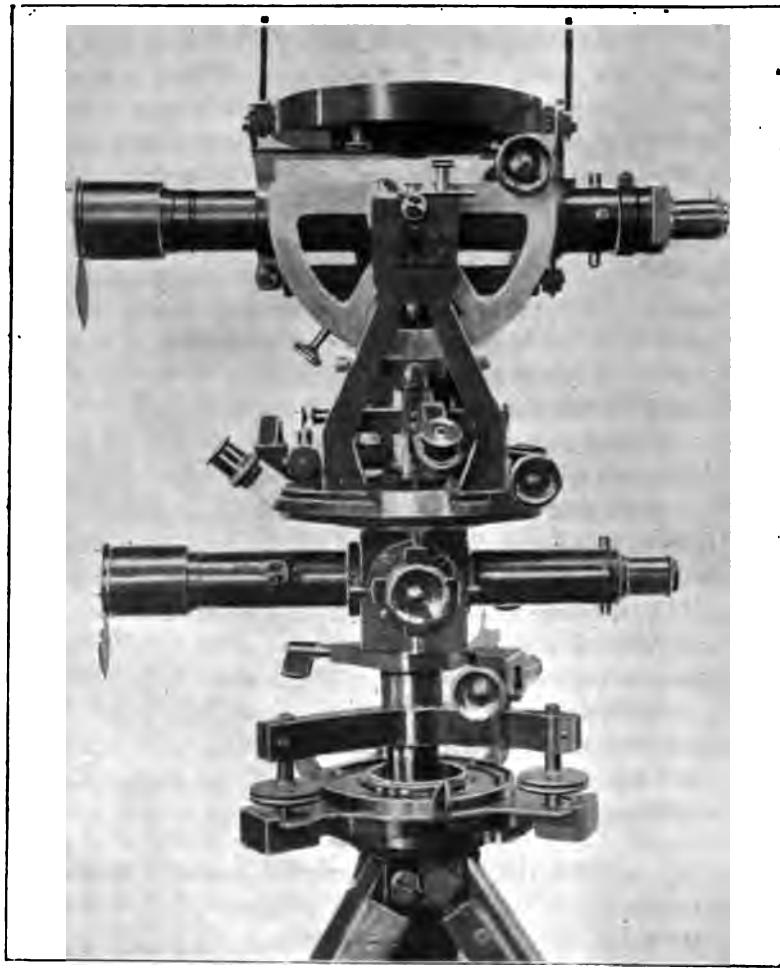


Fig. 11.—The Hoskold General Surveying Theodolite.

(1) it is an invention of new appliances; (2) its peculiarity, beauty, lightness, and novelty of construction; (3) it is adapted to facilitate surveying operations with greater accuracy and in less time than is usual with surveying-instruments; and (4) it is a general labour- and time-saver.

From Figs. 11, 12, 13 and 14, it will be seen that the instrument has two telescopes, the lower moving vertically upon its horizontal axis, in an oval or elongated slot-hole formed in the centre of the lower vertical axis which is attached to the under side of the

FIG. 12.—THE HOSKOLD GENERAL SURVEYING THEODOLITE.

divided circle, and its optical axis, or line of collimation coincides with the zero on that circle. In the same manner, the line of collimation of the upper telescope coincides with the zero of the verniers attached to the upper horizontal circle; consequently, when the instrument is in perfect adjustment and the zeros of the

verniers are made to coincide with the zeros of the lower horizontal divided circle, the optical axis of the two telescopes will be in the same vertical plane, which is proved by sighting to a fine distant point, and if the adjustments are perfect the

FIG. 13.—THE HOSKOLD GENERAL SURVEYING THEODOLITE.

vertical hair of each telescope will strike through the same distant point. When this adjustment has been made perfect, by screws attached for that purpose to the exterior sides of the lower vertical axis, there is no necessity to make the zeros of the verniers

coincide with that of the divided circle, each time it is required to take a horizontal angle, as is the general practice in traversing with other classes of instruments. By placing the two telescopes to look in an opposite direction, at the same time making a nice

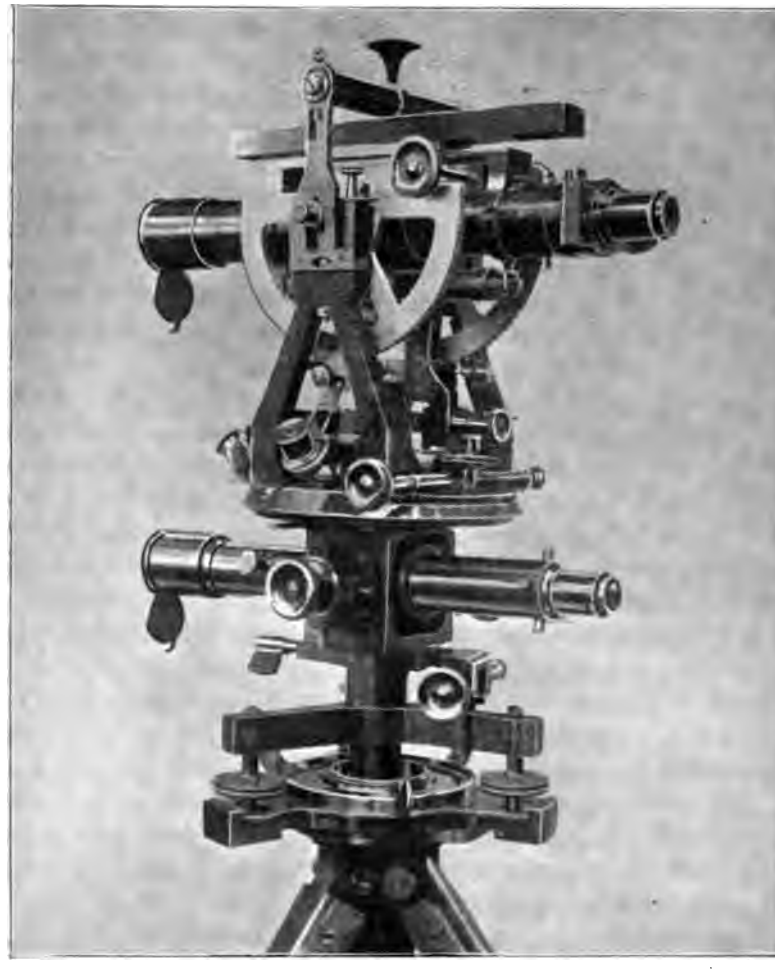


FIG. 14.—THE HOSKOLD GENERAL SURVEYING THEODOLITE.

coincidence of the verniers with 360, 90 and 180 degrees respectively, on the horizontal circle, the instrument can be used as a transit-instrument for such uses as it is generally applied, especially in prolonging a line in an opposite direction, and so dispense with the use of a high transit-theodolite proper, which, in

struction, contraction or expansion of parts, and other little accidents which may have occurred during the transit from one station to another; or it may be that the surveyor has accidentally touched the tangent screw to the divided circle and vernier, all of which would cause constant vigilance and a re-examination of the vernier coincidence when the fore observed angle is placed upon the back station. In point of time and accuracy, this latter mode of observing comes to the same thing as when the vernier-zero is made to coincide with the zero of the divided circle each time the horizontal angle is taken, without insuring greater accuracy.

To give to the new instrument an equal balance and insure greater precision in observing vertical angles, a semicircle is attached on each side of the upper telescope-axis, and close to the Ys, consequently, greater facility is obtained in reading, and, in this way, double angles are obtained at each observation. In foreign pioneering or expedition work, in difficult mountain-regions, where the difference of level has to be determined over long lines in precipitous places where spirit-level operations are next to impossible, double vertical angles are of considerable value, because, for greater precision, an average of two independent readings is more to be depended upon than a single one. In such difficult places, more common in foreign countries than in Great Britain, an assistant may, with great advantage, read the angle on one side of the instrument, and the engineer on the other. If, however, the work is not required to be so accurate, rapidity being more imperative, then the surveyor reads off the horizontal, and the assistant the vertical angle, so expediting the work to a considerable extent.

For colonial use and in setting out townships and locating large blocks of land, this instrument possesses great advantages. The lines to be measured, in such cases, must be set out at right angles to one another, and all that is necessary is to set the telescopes of the instrument at right angles, which is done by setting the verniers (A, B and C) to coincide with 270, 360 and 90 degrees, or with 90, 180 and 270 degrees respectively. The survey is then commenced and continued, nothing more being required, after levelling, than to place the lower telescope upon the back station: the upper telescope will then indicate the direction of the forward-line. If, however, any doubt should arise, and to insure confidence as the work proceeds, the coincidence of the verniers, with

the divisions noted on the divided circle, may be examined at every third or fourth station by a mere *coup d'œil*.

A prismatic reflector is mounted over a hole drilled into the wide part of the arm carrying each microscope, just behind it, the upper portion carrying the prism has a horizontal motion, and when it is turned, rays of light are reflected, and form a bright spot upon the vernier and that part of the divided circle, seen through the microscope. This is a very convenient arrangement and of great use when reading angles in dull weather or underground, and prevents the necessity of holding the light near the head when reading.

Each end of the horizontal axis, carrying the upper telescope, is perforated and a round pin carrying a small reflector at its end is fitted into one of the holes passing nearly to the centre of the telescope, for the purpose of reflecting the light from a lantern, through the hole in the opposite end of the axis, to the cross-hairs in the focus of the telescope, and by this means, they are illuminated, enabling an observer to bisect fine marks in dark places. An axis-level is provided for occasional use in making nice adjustments of the upper horizontal axis, and, consequently, placing the vertical hair in the optical axis in a vertical plane. This is tested by viewing a fine plumb-line, placed at a considerable distance; but, a more perfect plan is to bisect a star and its reflection in an artificial horizon, by a vertical sweep of the telescope.

A circular magnetic compass, with short plain sights to turn down, similar to the hinged dark glasses of a sextant, is also provided to be temporarily screwed or slid into a groove which is fixed on the top of the upper telescope. In that position, the face of the compass is free from obstruction, and may be read with great facility. When the divided circle of the theodolite is only 3·5 inches in diameter (the smallest size made) the magnetic needle of the compass is 3·75 inches long; but it may be made 4 inches without inconvenience. Each end of the needle carries a vernier subdivided to read to 1 minute or 30 seconds. When the circles of the theodolite are from 5 to 5·5 inches in diameter, the needle carrying the verniers may be from 5 to 5·25 inches long, and the verniers could be very well subdivided to read to either 30 or 20 seconds.

As an auxiliary, this part of the instrument is useful when a fine magnetic bearing is required at any point in an underground

survey for test-comparisons or other scientific purposes. When not so required, the compass is not attached to the telescope.

For land work, a trough magnetic compass is added, with a needle from 5·5 to 6 inches in length with only a few degrees of arc, and for use it is slipped into a long groove prepared to receive it under the lower divided circle, or temporarily screwed, or slid into the groove on the top of the telescope in place of the circular compass. A light staff or tripod is also added, upon which the circular compass can be mounted for taking bearings over small areas, or filling in minor details of surveys made by more accurate means.

By preference, three levelling-screws, with very large heads, move in a triangular frame which is fixed to the lower part of the theodolite. A separate triangular base-frame, to correspond, screws upon the top of the tripod-stand; and, by means of a locking-plate, which forms part of the base, the conical shouldered ends of the levelling-screws are firmly secured. The levelling-screws form an equilateral triangle, and having a free and independent movement one of the other, there is no locking or jamming or disturbance in position of the levels, due to opposing forces and other causes: as is the case when four conjugate levelling-screws are fixed opposite to one another in parallel plates in the ordinary manner.

It is this latter class of construction that has, in a great measure, caused the outcry as to the difficulty in levelling a spirit-level and a theodolite without the intervention of a Hofmann patent joint. By the use of three levelling-screws, every facility for quick and permanent levelling is offered, and whether the ground is level or inclined, it is only a question of expertness, and using judgment in selecting the stations. The writer does not believe in patent joints. The modern triangular levelling-base or frame, always used on the top of the tripod-stand, is connected to an ingenious movable centreing apparatus consisting of two thin plates with slot-holes, and short pins working at right angles: by this means it may be moved over a station until the plumb-bob indicates its exact centre, and then the whole is clamped by turning a circular female screw or concentric ring, also part of the centreing apparatus. By this means, a high-class approximation to geometrical precision in centreing over stations is attained, such as cannot be so conveniently attained by other means.

This arrangement is originally due to Messrs. Troughton & Simms, who constructed the new theodolite under discussion; and, in the writer's opinion, this fact alone is a sufficient guarantee that all improvements, which necessity and the art of facile and correct surveying could suggest or require, have been effectively carried out. Each telescope attached to a 3·5 inches theodolite of this class is 9 inches in length, mounted with an object-glass of 1⅛ inches aperture, and in a clear atmosphere is capable of reading a station-pole at a distance of 1¼ miles: by employing a reflecting lens, heliotrope or other efficient apparatus for throwing the rays of the sun or electric light forward, even a greater distance may be reached. The telescope of a 5 inches instrument is from 10 to 11½ inches in length, with an object-glass varying from 1¼ to 1⅝ inches in diameter, and should command a distance of 1·75 to 2 miles. The telescope may, however, be longer.

The telescopes, levelling-frame and all the heavier parts of the instrument are made of composite aluminium metal, but the centres, bushes, screws and other frictional parts are made of the ordinary metal employed in making instruments. The weight of a 3·5 inches, and that of a 5 inches instrument is comparatively small, so that the most fastidious should not have any well founded reason for objecting to the general use of a theodolite of this class, on account of excessive weight, cumbrous mechanism, complication of parts, or expense.

The size of instrument best adapted for use must depend upon the nature and extent of the work to be performed; but for foreign and home work, both on the surface and underground, the choice may range from 3·5 to 4 inches in diameter (divided to read to 30 and 20 seconds) to between 5 and 5·5 and 6 inches in diameter, with verniers subdivided to read from 20 to 15 seconds. The latter two sizes would well bear to carry micrometrical microscopes subdivided to read to from 10 to 5 seconds. With such instruments and good manipulation, the maximum error in any single observation should never exceed the least amount of angle that the vernier or micrometer-microscope is capable of indicating, and in performing circuitous surveys, or what is known as forming "the irregular polygon," such other small errors than those which can be appreciated with a 20, 15, 10 or 5 seconds vernier would have the tendency to balance one another, leaving the survey less affected. Still, it is recognized that small angles of a few seconds

which cannot be measured are accumulative: it frequently occurs that when a polygon is completed, an error of from 2 to 4 minutes will exist, and it is customary to distribute such a difference between the measured angles or those most likely to contain the error. But, considering that it is not always possible to complete the polygon, namely, returning to the point of commencement, underground by another route, some other special means should be adopted in order to prove the work at each station.

The most effective and practical mode of doing this is, in addition to the angle itself, to observe the supplementary angle at each station. The two angles should then amount to 360 degrees, or close to it, depending of course, as previously noted, upon the fineness of the subdivisions of the verniers employed. Suppose, for example, that the observed horizontal angle is 174 degrees 51 minutes 30 seconds, and the supplementary angle amounts to 185 degrees 8 minutes, then 174 degrees 51 minutes 30 seconds, plus 185 degrees 8 minutes, equal 359 degrees 59 minutes 30 seconds, introducing an error of ½ minute.

We may, however, obtain a better result by employing a vernier reading to 15 seconds, for 174 degrees 51 minutes 45 seconds, plus 185 degrees 8 minutes 15 seconds, equal 359 degrees 59 minutes 50 seconds, or only 10 seconds from the truth. The difference in each case, however, is an error, but the one is three times greater than the other, and if the survey went in any general direction, without forming the polygon, neither of the errors noted would have been discovered if the supplementary angles had not been observed. Such errors may be of frequent occurrence, and as previously noted, are accumulative, so that, in a long survey, it would be difficult to say how much the deviation from the truth would be at the end of the survey. No doubt, an instrument for underground work is best fitted with verniers, unless large-sized drifts or tunnels are to be constructed and then 5·5 or 6 inches instruments reading to 5 or 10 seconds could be used with great advantage, and would be best divided upon platinum, which is less liable to be scratched and more easily cleaned.

Figs. 11, 12, 13 and 14 represent the theodolite under discussion, which, as the writer believes, is one of the most perfect instruments in existence. It differs in a few details from those of the same class previously constructed. The horizontal circle is 5 inches in diameter, divided upon platinum to 15 minutes, with 3

double-verniers subdivided on gold to 15 seconds. It has a micrometrical eye-piece reading to 1 second, and is intended for the purpose of measuring small angles in determining distances by the subtense process, previously noted, as also as an auxiliary in connection with the measurement of coarser angles read from the divided circles. This operation is effected as follows: an angle is measured, say 160 degrees 25 minutes 45 seconds; but it is considered that there may exist a small angle of a few seconds of arc, which cannot be measured by the 15 seconds vernier. In such a case, the tangent-screw attached to the horizontal vernier-circle is turned backwards until the reading is made to the nearest minute, or 5 minutes, as the case may be, say 160 degrees 20 minutes 45 seconds. The vertical hair in the optical axis of the telescope will then appear a little to the left hand of the station-pole or line. The vertical hair or zero of the coombe of the micrometer is then placed in contact with the vertical wire of the telescope and the distance to the station-pole or line is measured in minutes on the coombe and the seconds upon the micrometrical divided head. The angle on the coombe is 0 degrees 5 minutes 0 seconds and on the micrometrical head 0 degrees 0 minutes 11 seconds, or 0 degrees 5 minutes 11 seconds plus 160 degrees 20 minutes 45 seconds, or a total of 160 degrees 25 minutes 56 seconds, the angle required. If the nearest minute only had been taken, then the small additive angle would have been 0 degrees 1 minute 11 seconds. To obtain the advantages of this plan, the station-objects to be sighted should be very fine and clearly defined.

A short horizontal cylindrical-formed bearing is screwed on each outer opposite side of the lower vertical axis; into the extreme end of the bearing a circular collar or ring is inserted a little less in diameter than the internal diameter of the cylindrical bearing, the ends of the telescope's horizontal axis being fitted into the collars. Four screws work through the sides and at the termination of each cylindrical bearing, and these press against the internal rings or collars referred to, consequently a slight movement given by the adjusting-screws produces a corresponding movement in the ends of the axis and telescope, in a vertical or horizontal direction, and, in this manner the vertical hair of the telescope is made to coincide with that of the upper telescope, when the zeros are made to coincide with 360, 180 and 270 or 90 degrees. The ends of the lower horizontal axis are

suspended in the collars and between the adjusting-screws in the cylindrical bearings, at a sufficient distance from the optical axis of the telescope to prevent lateral vibration, supposing that pressure were applied to the telescope.

The lower telescope has a vertical range of a few degrees, sufficient for most terrestrial observations, but when the objects to be observed are too elevated or depressed, a plane mirror or reflector is attached to the object-end, and, by this means, they may be seen through the telescopes nearly up to the vertical or in the nadir.

The plain short sights of the magnetic compass are mounted in pairs on each opposite side, or diameter of the compass-box, one on each side being an open sight, and the other a fine one, so that an object may be viewed through them from alternate sides when the lines are too short to be observed by the telescope. The open sights consist of a short piece of glass with circular ends, mounted in a metal frame, the cross lines being engraved upon it. These sights move on a hinge or circular pin, and may be turned down out of the way when it is necessary to read the fine divisions of the verniers attached to the needle by means of a microscope. (Figs. 11, 12, 13 and 14 show the instrument in different positions with its principal details.) Since this instrument has been constructed, the writer has realised an invention by which a long and powerful telescope may be mounted upon short Ys, and made to revolve vertically in the same manner as is usual when a transit-theodolite telescope is mounted upon high Ys.

About 1868, the writer also designed a mine-surveying theodolite of the eccentric class, and in 1870 he obtained a patent for the instrument, which was denominated by the distinctive name "angleometer." A miner's dial was also constructed on the same plan. These instruments were exhibited in the Section of Scientific Instruments in the International Exhibition of London, 1872, and a certificate of admission was given, the only recompense accorded to exhibitors. The angleometer is compactly constructed, has but little height, and is not liable to any vibration like some others with telescopes mounted on very high standards or Ys, and is specially adapted to mine-surveying. The vertical circle on one side is connected to a horizontal axis mounted across the vernier-circle, and terminates on the opposite side into a short cylinder in which the telescope is fixed. Mr. Arthur Beanlands'

process of connecting underground workings to the surface is therefore easily effected by it, when the depth of the shaft is not great. It may also be employed for taking the zenith-distance of stars for latitude, time and other determinations. This instrument has a magnetic compass, the same size as the horizontal

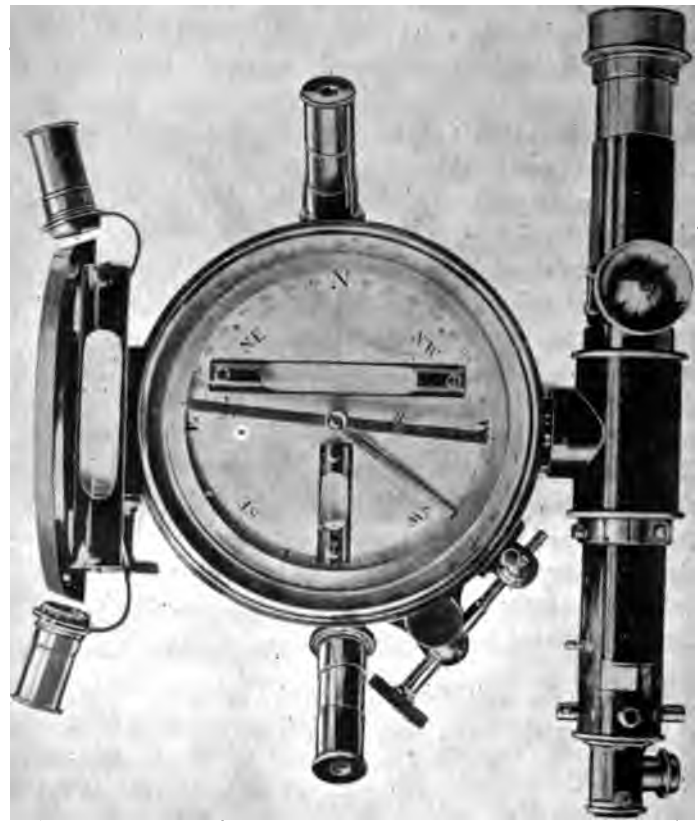


FIG. 15. THE HOSKOLD ANGLEOMETER OR GENERAL SURVEYING INSTRUMENT.

vernier-circle (5 inches in diameter). The needle carries a vernier at each end reading to 20 seconds.

The instrument is well balanced, and is suitable for use underground, especially in low places where it would be difficult to use a higher and heavier instrument.

Fig. 15 is a view looking down upon the face of the instrument, and Fig. 16 is a side view, or elevation of it, exhibiting the form and arrangements of the vertical circle, telescope and other parts. It will be observed that the horizontal axis, carrying the vertical circle on one side and the telescope on the other, is

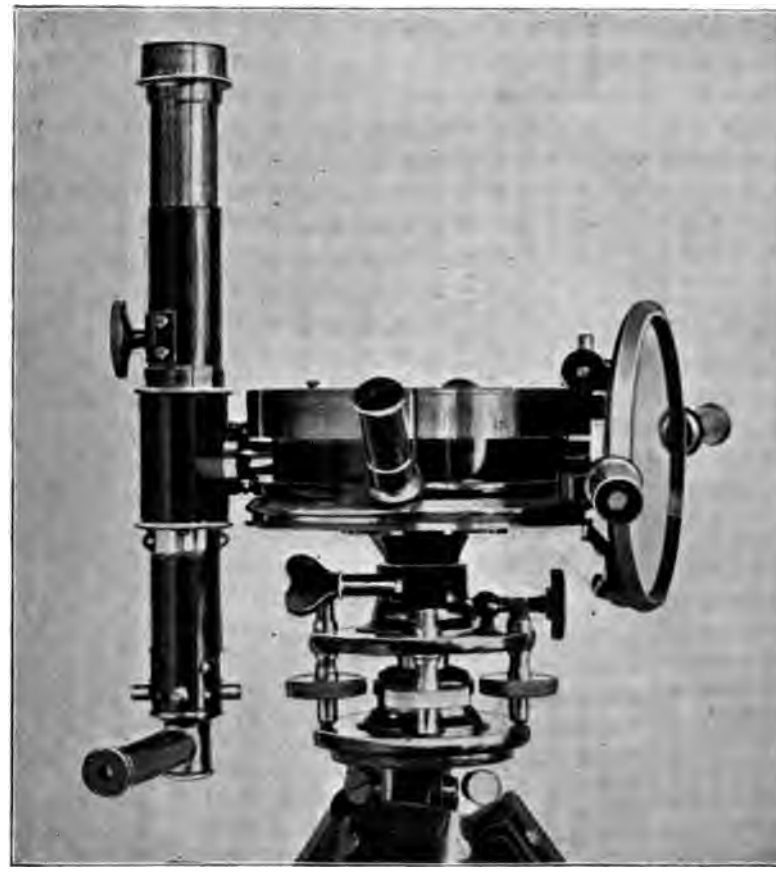


FIG. 16.—THE HOSKOLD ANGLEOMETER OR GENERAL SURVEYING INSTRUMENT.

mounted across and close down in very low bearings upon the vernier-circle of the instrument. The outer ring of the compass-box extends downwards to join the vernier-circle, so that the horizontal axis, low bearings, etc., do not appear. Originally, the angleometer was mounted upon parallel plates and four conjugate levelling-screws; but it would be more steady if mounted upon a

triangular frame and three levelling-screws. The telescope can be revolved about its optical axis for collimating purposes. Near the eye-piece end of the telescope, a square perforation is made and a curved piece of glass framed in it through which light passes to illuminate the cross-hairs. A slide-shutter is provided to protect the glass, and to prevent light from entering when the instrument is used on the surface.

Similar instruments have been constructed in France, with telescope and vertical circle on the same side, and a dead-weight on the opposite side as a balance. The late Mr. Combes used an instrument of this sort for mine-surveying in 1845.

In 1869, Mr. Casella introduced a very small instrument of this class for travellers' use; it has a magnetic compass on the top of the vernier-circle, but he placed an horizontal axis across the face of the compass working in short Ys, with a vertical circle attached to the axis on one side, and a telescope on the other. He also placed a spirit-level on the top of and at right angles to the axis, so that the face of the compass was completely obscured.

Surveying-instruments have been made in Germany, with the telescope and vertical circle mounted upon the same side, but upon much higher Ys than that of Mr. Casella. Another form of theodolite is also made in Germany, with the horizontal axis mounted upon Ys with the telescope on one side, the vertical circle on the other, and a long spirit-level mounted in the direction of and upon the axis. These instruments are not fitted with a magnetic compass.

Objections have been raised to the use of eccentric instruments for surveying, because it is argued that an angle taken with a telescope, or plain sights, on the side of, and revolving round the circumference of a circle, is not the same as it would be when the telescope is mounted over its centre. However, to obviate this difficulty, French and other makers have employed double-sighting targets with circular discs, the centres of the two being set at a distance from one another equal to half the diameter of the theodolite-circle and telescope. As in Mr. Combes' case, the targets are mounted upon a frame-tripod, with a telescope in its centre, so that an assistant may direct the telescope from a forward station or otherwise, to the telescope of the observer's theodolite: the discs would then be in a position to be sighted to. To avoid any such inconvenience, if the horizontal angles formed by the roads in mines were to be observed by the angleometer from

station to station in the usual manner (without the use of targets) and plotted on the plan with a circular protractor constructed with a flat bar working tangentially round the circumference of the circle, with folding arms, and steel prickers to mark off the

FIG. 17.—THE HOSKOLD MINER'S DIAL.

angles, precisely the same results would be obtained as when the angles are observed with an ordinary theodolite and plotted with the common form of circular protractor.

Fig. 17 represents the miner's dial, previously referred to, mounted upon a triangular levelling-frame with three levelling-screws. The needle carries verniers reading to one minute, and the spirit-levels are fixed in the plate forming the face of the instrument. The vertical arc also reads to one minute, and is attached to the end of an horizontal axis on one side, and the plain sights are attached to the opposite end of the axis on the other side. The short bearings in which the axis is mounted are placed below the under plate of the compass-box and are not visible. A sensitive spirit-level is placed upon the flat arm carrying the plain sights. This instrument is convenient for use as a simple miner's dial.

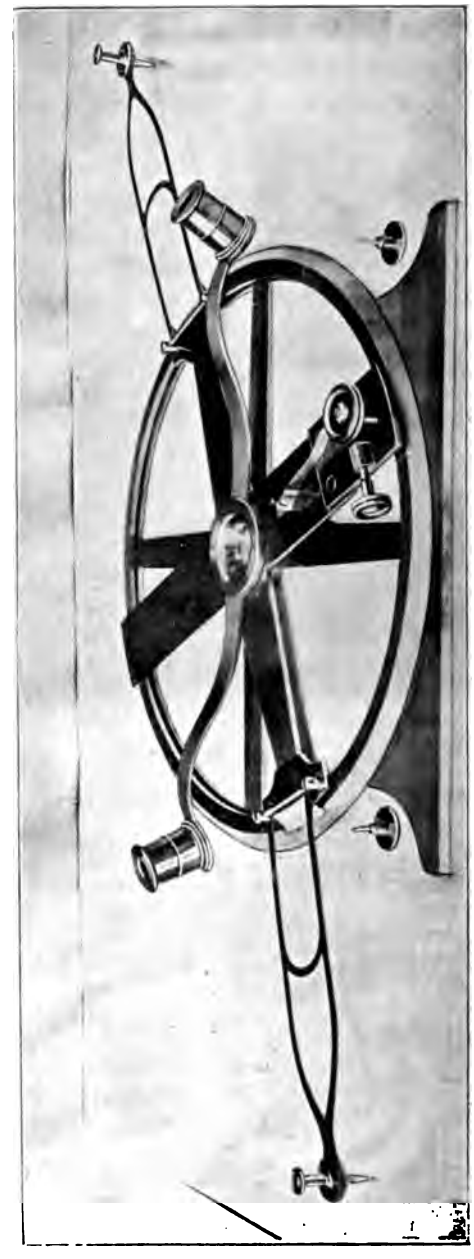


Fig. 18.—The Hoskold Circular Protractor.

Fig. 18 represents a new form of circular protractor, made by Messrs. Troughton & Simms at the suggestion of the writer many years ago. It is 10 inches in diameter, is divided to read by verniers to 5 seconds, and instead of being graduated upon a flat surface, which is incon-

venient to read, the graduations are placed upon a levelled edge like the limb of a theodolite, and offer greater facility for reading. It is provided with two microscopes revolving in arms radiating from the centre. Instead of steel prickers, fine pencil-points are mounted at the ends of the folding arms, so that angles may be marked off without leaving punctures in the paper. It has a bracket-formed piece of brass cast to one side of the circle, and by this means the protractor may be slid along a steel straight-edge placed against the meridian-line, enabling angles to be plotted from different points of the map, when the angles in a traverse survey are very numerous, the paper long, and the scale large. This obviates the inconvenience of transporting many angles to a long distance with a rolling parallel-ruler. This protractor is a superior instrument, and is well adapted for plotting the angles taken by the theodolite (Fig. 9). For ordinary work, smaller instruments of the same class may be constructed.

Fig. 19 represents the miner's transit-theodolite, introduced by the writer in 1863, as already noted. It is, however, to be preferred mounted upon a triangular levelling and centreing frame apparatus, instead of the old fashioned parallel levelling-plates.

Some years ago the original makers, at the recommendation of Mr. Richards (without the consent of the writer), made that part of the instrument between the upper parallel plates and the horizontal circle much longer than in the original model, with a view, as it seems, of forming a joint above the parallel plates as a supposed ready means of disconnecting the instrument from the parallel plates and tripod and rendering it interchangable with a reflecting sighting-disc, also mounted upon levelling parallel plates and tripod similar to that of the theodolite.

These tripod-legs consist of metal tubes sliding one into another and clamped at variable heights by thumb-screws. In this form it is stated that the instrument is much used in South America. However, the extra and unnecessary height given to the theodolite by this alteration, with tubular legs will, after considerable use, prove a fertile source in producing serious vibration of the upper parts and rickety movement in the lower ones, sufficient to vitiate the observations. If, instead, the instrument had been mounted, as suggested above, every facility would have been afforded for ready interchange with the sights by employing

three short modern wooden tripod-stands without risk of vibration, besides being much more convenient for use.

FIG. 19. THE HOSKOLD MINER'S TRANSIT-THEODOLITE.

Some years ago the writer contrived a tripod-stand, the legs of which consisted of brass sliding-tubes fitted with clamp-screws so as to adjust the stand at various heights, but consequent upon

bad construction and too great weight, he found the plan a complete failure.

It may be of service to note that various tables for co-ordinate plotting of traverse surveying have been published from time to time. Gales' Tables, 1791, read to 15 minutes to 3 decimal places and from 1 to 100 units of distance. Hutton's two-page tables read to single degrees and to 4 decimal places. Fenwick's tables, 1804, also read to single degrees, to 2 places of decimals and from 1 to 100 units of distance. These tables have since been published by Mr. T. Baker, as also the work of Mr. T. Fenwick on *Mine Surveying*. Major-General Boileau's tables (1839), have an improved form reading to every minute, to 5 decimal places and only from 1 to 10 units of distance. Its contracted form involves greater labour than would have been the case supposing it had been extended to embrace a higher number of units of distance.

The *Traverse Tables*, published by the writer in 1863, read to every 2 minutes and by differences to any fractional part of a minute, to 6 decimal places, and, by a peculiar arrangement, from 1 to 500,000 units of distance without occupying more space than the tables published to 100 units. In 1871, he extended his original table to read to every minute, and by differences to any fractional part of a minute and from 1 to 20,000,000 units. The length of the sides or co-ordinates of all possible right-angled triangles within these limits are tabulated, consequently any quantity is obtained by a mere inspection. This MS. table is still in his possession and in use.

Gurden's *Traverse Tables* read to every minute and like Fenwick's only from 1 to 100 units of distance; but extend over 44 large folio pages. Their large size renders them awkward for general reference. Various other tables of a similar class have also been published, more or less useful.

It need scarcely be noted that traverse tables are great labour-savers, affording ready means for calculating and verifying the accuracy of a survey before constructing the plan. Plotting maps and plans by taking out the co-ordinates from such tables is vastly superior to the employment of the best class of protractors, for the reason that, if an error is made, it accumulates, while on the contrary, each co-ordinate is independent of the other. For those who prefer to expend more time and labour in such calculations,

the common tables of natural sines and cosines, etc., as also logarithmic sines, cosines, etc., with the logarithms of numbers, are all that could be required.

It was understood that the Institution should reproduce in its *Transactions* the paper upon "Geodetic Surveying Operations," which the writer was solicited to prepare and read before the International Congress of Engineers, Chicago, 1893, and published in the *Transactions* of the American Society of Civil Engineers,* New York; but he considered it necessary to modify and extend the contents of the original paper and present it in its present form, constituting, as it does, a distinct paper.

The PRESIDENT (Mr. H. C. Peake) moved a vote of thanks to Mr. H. D. Hoskold for his valuable paper.

Prof. H. LOUIS seconded the resolution, which was cordially approved.

Mr. THOMAS WARD read the following paper on "The Subsidences in and around the Town of Northwich in Cheshire":—

* Vol. xxx., pages 133 to 156.

THE SUBSIDENCES IN AND AROUND THE TOWN OF NORTHWICH IN CHESHIRE.

By THOMAS WARD

To understand the Northwich subsidences, it is necessary to know the position and peculiarities of the salt-beds, which underlie the district—the removal of these beds, or portions of them, being the cause of the subsidences (Fig. 1, Plate VIII.).

It is not necessary to go fully into the geology of the Cheshire Salt formation as it does not materially affect the question of subsidence. It may suffice to say that the Cheshire salt was deposited in the Triassic period, during the time when the Keuper Marls were being deposited. It would probably be more correct to consider the salt as an accompaniment of this period of marls, than the marls as an accompaniment of a great salt-age. The salt-beds contain marl to a very large extent, only a very small portion of the rock-salt being pure, that is, free from marl. To make this quite clear, a summary of the strata found in a boring at Marston, near Northwich, is given in Table I. This boring passed through the thickest portion of the salt-beds and was carried to the depth of 2,610 feet with the hope of finding Coal-measures. At this depth the boring was still in the New Red Sandstone, with marl-seams.

Table I.—Section of Boring at Marston.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Soil, Boulder Clay and sand ...	31	9	31	9
2	Keuper, or Salt-marl	92	3	124	0
3	First Bed of **ROCK-SALT** ...	90	6	214	6
4	Hard marl with *salt-veins* ...	27	11	242	5
5	Second Bed of **ROCK-SALT** ...	91	9	334	2
6	Marl, with traces of *salt*	30	8	364	10
7	**ROCK-SALT**	5	2	370	0
8	Marl, with traces of *salt*	8	2	378	2
9	**ROCK-SALT**	12	6	390	8
10	Marl, with traces of *salt*	23	6	414	2
11	Marl	879	7	1,293	9
12	Sandy marls and sandstones with marly joints	1,316	3	2,610	10

The Keuper Marl, in which the salt is found, accounts for a thickness of 1,262 feet; and the section of it in which the rock-salt occurs for 290 feet 2 inches, and of this the salt-beds form 199 feet 11 inches.

For the purposes of this paper, it will only be necessary to deal with the upper 334 feet 2 inches of the section, namely, from the surface to the bottom of the second bed of rock-salt, as the whole of the subsidences occur in this portion. It will be seen that there are two main beds of rock-salt, separated by a bed of marl, 27 feet 11 inches thick.

FIG. 12.—VIEW OF SUBSIDENCE IN CASTLE STREET, NORTHWICH.

The two beds are locally known as the "Top Rock-salt" and "Bottom Rock-salt" or "First Bed" and "Second Bed." Overlying the First Bed is one of salt-marl of the same nature as the marl which is found intimately mixed with the rock-salt. It has evidently been deposited in the same geological period, and in the same salt-lake, as the salt itself, but at a time when the water contained much less salt in solution, or the seasons were not sufficiently hot and dry to evaporate water enough for the salt to crystallize out. Salt does not form until saturation-point is reached, that is, until there is about 26 per cent. of salt in the water. This salt-clay or marl, is similar in colour to the overlying Boulder Clay, but is free from the pebbles, sands and gravels which accompany the latter.

Countless ages passed between the period when the salt-clay was deposited and the time when the Boulder Clay, sands and gravels were deposited immediately upon it. It is almost certain

that there had been other deposits, in the interval, on the salt-marls, which had been eroded.

The upper surface of the salt-marl is most irregular, being covered with ravines and furrows, which are filled by drift. These depressions show extensive denudation by water at the surface of the salt-marl, and similar furrows met with on the surface of the First Bed of rock-salt, also indicate the action of water. The furrows and miniature valleys now mentioned must not, however, be confounded with the similar depressions artificially produced, that form one portion of the subsidences mentioned in this paper.

FIG. 13.—VIEW OF SUBSIDENCE IN CASTLE STREET, NORTHWICH.

In the neighbourhood of Northwich, the subsidences which occur are more complicated than those met with in other parts of Cheshire. This is mainly owing to the mining of the Upper Bed of rock-salt, though, as will be seen later on, the mining of the Lower Bed has been instrumental in some of the worst cases. The great cause (though not quite the only one) of the subsidences is water, and the action of water on beds of salt will explain the subsidences which are going on daily, and at intervals are intensified by the sudden rush of a great body of water into the old mines.

The writer proposes to deal first with the simple subsidence not complicated by mining. This occurs on the surface of the First or Upper Bed of rock-salt, which covers probably a little less than 2 square miles. It has been proved to be non-existent at a number of points east, south and west of the Marston bore-hole (of which a section has been given) but its northern limit has not been

determined. The writer gives a section of this Upper Bed of salt on a line passing from east to west through the Marston bore-hole (Fig. 2, Plate IX.). It will be seen that there is a gradual thinning off of the salt-bed both eastward and westward. A section from north to south shows the same thinning off, but not quite so rapidly as the former (Fig. 3, Plate IX.).

As the bottom of the Upper Bed is practically at the same level throughout, there cannot be any doubt that the salt-bed when first formed or deposited had practically a level surface and was equally thick throughout. The present condition of the surface shows

FIG. 14.—VIEW OF SUBSIDING HOUSE IN CASTLE STREET, NORTHWICH.

evident marks of erosion by water. This erosion must have taken place before the period of the deposit of the Boulder Clay, as the surface of the land does not follow the contour of the underlying salt-bed.

The surface of the First Bed of salt is furrowed and channelled all over, some of the furrows are shallow while others are very deep. The power of water to eat away rock-salt is shown very clearly by these furrows, but more so by the serious subsidences occurring on large portions of the surface of the land overlying the salt-bed. Rock-salt is very soluble in water, and when fresh water reaches a bed of salt, it proceeds to dissolve it, until the

water contains about 26 per cent. of salt. When this point is reached, the saturated brine ceases to attack the salt, and if not removed, no further solution of the salt occurs. Water in motion saturates itself more quickly than water at rest.

In a natural state, before man intervenes, the water overlying a salt-bed is only removed by brine-springs, and these springs in almost every case carry off the upper or weak portion of the brine, while that lying upon the salt is saturated. The salt carried away by these springs in the course of ages lowers the surface of the salt-bed, but as the whole surface is equally acted on (there being little motion of the water over the salt, the brine-springs being small in almost every case), there is not sufficient erosion to cause any perceptible sinking of the overlying land.

It is this very slow action which causes an imperceptible lowering of the whole area overlying the salt, that has to be contrasted with the rapid subsidences of to-day, which are so marked over certain defined areas. Subsidences, of the nature of those in Cheshire, only occur when man proceeds to remove the water overlying the salt-beds more rapidly than the natural brine-springs had been doing.

In early days, only such brine as made its appearance in springs was used by man for the purpose of abstracting the salt, and the quantity of salt so made was very small. As the demand for salt increased, the brine, rising to the surface in springs, became gradually exhausted, and it was necessary to sink wells to follow its lowering level. As old springs or wells became exhausted new ones were sought for, and instead of fetching the brine out of the well by buckets, pumps were used, and the quantity of brine obtained from the wells thus sunk became much larger than that originally flowing away in the natural brine-springs.

Every pump became a centre towards which the salt water flowed, and as this was removed from over the salt-beds fresh water from the immediately adjacent strata flowed in to supply its place.

As soon as this fresh water came into contact with the rock-salt it proceeded to dissolve it and to saturate itself with salt. It was some considerable time after pumps were introduced before any perceptible subsidence took place on the surface of the land. This was owing to the existence of an extensive basin filled with brine, the accumulation of ages, the upper portion only of which

had flowed away in the springs. This basin was the remains of the old salt-lake in which the salt had been deposited.

The pumps, for a long period, having been but few, the motion of the brine towards them was slow, and the action on the salt-bed wide in area but only slight. About 130 years ago, the demand for salt increased, more and larger pumps were put down, a more rapid circulation of the brine over the salt-bed took place, and there followed, consequently, a more rapid dissolution of it. For at least 120 years, the demand for salt continued to increase, and steam was employed instead of windmills to do the pumping.

The level of the brine was rapidly lowered, each pump became

FIG. 15.—VIEW OF SUBSIDING HOUSE IN CASTLE STREET, NORTHWICH.

a centre towards which the brine travelled rapidly, and the fresh water travelled with equal rapidity to take its place. Instead then of there being a gentle even flow over the whole surface of the salt-bed and a slight imperceptible lowering of its level, the fresh water cut channels on the salt in the direction of the pumping-centres.

These channels widened and deepened until the water had taken up as much salt as it would contain, and then they died away as they approached the pumping-centres. Where the fresh water first came into contact with the salt, the dissolution was the most rapid and extensive.

As the level of the salt-bed was lowered the overlying marls followed, and the contour of the salt-bed was repeated on the surface of the overlying land. The marls, breaking and cracking in following the sinking salt, allowed more water to pass down and so intensified the subsidence (Fig. 4, Plate IX.). Where a channel on the salt-bed crossed under a brook or river on the land-surface, water passed freely down, and very soon, owing to the more rapid dissolution of the salt at the spot, and the consequent subsidence of the surface a lake formed; even where no brooks or rivers existed, lakes were formed, owing to the unequal subsidence of the underlying salt-bed. This unequal sinking was

FIG. 16.—VIEW, TAKEN IN NOVEMBER, 1898, OF SUBSIDENCE IN LONDON ROAD, NORTHWICH.

caused by the salt being much purer in some portions than others, that is, it contained less marl. It will be easily seen that where there is 90 per cent. of salt and 10 of marl the sinking will be greater than where there is 90 per cent. of marl and 10 of salt. The salt dissolves and is carried away, the marl remains, and though some is at first held in solution, it falls before the pumping-centre is reached and none is pumped up with the brine. Muddy brine would be useless for salt-making.

If the marl be very tenacious in places, and the overlying rocks consist of strata not easily broken, large cavities are formed in the course of the travelling brine: but as soon as the roof of the

cavity acquires a bearing too large to support the superincumbent rocks, it breaks and falls in, carrying these with it, forming a large pit on the surface which soon fills with water, the marls and clays having puddled themselves and made a water-tight bottom to the pit. Occasionally, where the puddle is not sufficient, or where the salt below still continues to be eaten away by the fresh water, the bottom of the pit gives way and the water contained rushes into the cavity and thus increases the area of the pit.

In and around the town of Northwich, there are subsidences of the kind just named, occurring at frequent intervals, but they, as a rule, are much smaller than those in the Winsford district.

Near Northwich, the beds of sand in the Drift are very thick, and the salt-beds lie comparatively near the surface, consequently the marls and clays of the salt-formation which intervene are thin, and when a cavity is formed by the dissolution of the underlying salt, they break down and let the overlying sands and earths into the cavity. These sinkings occur most frequently on what appears to be the outcrop of the Upper Bed of rock-salt, adjacent to the rivers Weaver and Dane. They are very troublesome, as they frequently break up the main roads leading out of the town, and carry down the adjacent buildings or render them uninhabitable. (Figs. 12, 13, 14, 15 and 16).

To sum up, the subsidences occurring over the Upper Bed of rock-salt, and caused by the action of water alone, are either in the form of depressions on the surface, more or less deep, which in many cases become filled with water and form lakes, lakelets, or pits (Fig. 17); or where the drainage is not interfered with, resemble dry river-beds.

Where the streams of brine flowing to a number of large pumping-centres collect into one course, and the salt is very thick, the earth above this course follows the dissolving salt, and the adjacent lands on either side of the deepening valley break off and form steps in adapting themselves to a line of rest. As the valley deepens, the steps increase in number, and form farther back, until the area included in the sinking valley is greatly extended and the land is broken up.

This phenomenon, although common near Northwich, is best seen along the course of the river Weaver, south of Winsford, where very large lakes are forming. The best illustrations at the moment of the formation of small lakes and shallow depressions

are in the immediate neighbourhood of the London and North-Western railway, from Northwich to Crewe. The largest and oldest of these lakes is at Billinge Green, between Northwich and Middlewich. Between Sandbach and Crewe, a number of these depressions can be seen, especially after wet weather, when the water shows them up very distinctly.

Shortly after 1670, when the First or Upper Bed of rock-salt was discovered in the neighbourhood of Northwich, shafts were sunk and the salt mined and shipped to the Mersey for exportation. The quantity raised was very small at first, being about 7,000 tons for the first year (1734), after the river Weaver was made navigable. For 50 years from that time, the Upper Bed of

FIG. 17.—VIEW OF LAKE, DUNKIRK, NORTHWICH, FORMED BY THE SUBSIDENCE OF LAND.

rock-salt was mined; but at no time did the quantity raised in a year exceed 50,000 tons. The mines were all very small. The First Bed of rock-salt in its thickest portion was about 90 feet thick, but the more usual thickness, in the part of it where the mines were worked, varied from 70 to 80 feet. Out of this, a portion varying from 30 to 40 feet was mined, and pillars varying from 12 to 21 feet square were left to support the overlying salt and strata (Fig. 9, Plate X.).

As far as can be seen by the few plans of these mines that are to be met with, and by the only Top Mine (as they are called) now in existence, the pillars seem sufficient to support the roof (Figs. 5 and 6, Plate IX.). Not many years after the first mines were sunk they began to fall in, owing in almost every case to fresh

water or bastard brine, that is weak brine, finding its way into the shafts. It was not found so easy to tub out water then as now (there being much more of it), and consequently, the water finding its way into the mine commenced to eat away the salt round the shaft, and to undercut the pillars supporting the roof. In a short time the mine filled with water, and the shafts, having their supporting pillars eaten away, collapsed, letting down the overlying earths into the mine, and forming a deep pit, with the shaft as a centre. The marls and clays soon formed a puddle, and the pit filled with water. These pits, of which a number still remain in the neighbourhood of Northwich, are locally known as "Rock-pit holes" (Fig. 7, Plate IX.).

Those now existing are on fairly high land, the others that were on the low land near the river Weaver, and the brooks running into it, are now beneath the large lakes, owing to the surface of the Upper Bed of salt being lowered by the brine pumped in the district, as before described (Fig. 8, Plate X.).

From 1750 to 1785, there are records of the constant destruction by water of the salt-mines. After 1781, all new mines were sunk to the Second Bed of salt, then recently discovered, and although the destruction of the remaining Top Mines was not so frequent, yet, at intervals up to the present time, we have instances of their falling in. Only one is now known to exist, and it is very interesting. As the Top Mines were worked, leaving only a thin crust of salt between the cavity and the overlying rock, this was soon eaten through if a brine-stream flowed over it, as many of them did; and when this happened the subsidence was greatly intensified. Most of the large lakes and subsiding areas have been formed by this union of the ordinary brine-sinking caused by the dissolution of the Upper Bed of salt and the falling in of the Top Mines of rock-salt underlying the sinkings. In one or two instances, the falling in of the Top Mine was caused by the collapse of the supporting pillars; but almost invariably water has been the cause of the trouble (Figs. 9 and 10, Plate X.).

The rock-salt trade increased very rapidly, after the time when the mines commenced to be sunk to the Bottom or Second Bed of salt, say from 1781, till there was regularly raised for about a century more than 100,000 tons of rock-salt per year. The result of this extensive mining of salt in a limited area was, that mine

after mine was worked up to its boundary and then abandoned. The manufacture of white salt also increased very largely at the same time, and most of the brine formed on the Upper Bed of salt became exhausted.

Water found its way into many of the abandoned mines, and by eating away the salt, formed a fully-saturated brine; and the owners of these mines proceeded to pump up the brine and use it for salt-making.

In time, the brine in these mines became exhausted, and if there were adjacent mines full of brine, but unpumped, a communication was made so that the brine could be tapped. In mining also, on several occasions, the working mine broke into an abandoned one, and was itself destroyed, except as a reservoir for brine. A great number of mines thus became connected and formed one or two huge reservoirs covering many acres. Large as these reservoirs were, they became gradually pumped down, and on several occasions, where the Bottom Mines had been worked under old Top Mines, which lay under brooks and rock-pit holes, the overlying water found its way down the shafts or through rifts in the roof into the mines and filled the reservoirs once more. The fresh water, on its way through the rock-salt to the cavity of the mine, rapidly dissolved the salt.

FIG. 18.—VIEW, TAKEN IN DECEMBER, 1880, OF CHIMNEY, DAMAGED BY SUBSIDENCE AT ASHTON'S WORKS.

The Lower Mines were worked, generally, so as to leave a cavity from 13 to 18 feet deep, though occasionally as much as 25

to 30 feet of salt was taken out. This salt, so abstracted, formed the lower portion of the salt-bed, which was generally nearly 90 feet thick. Whenever there was an inrush of water on a large scale, as in December, 1880 (when a brook of considerable size and a large body of water from the river Weaver poured into the old mines for nearly 10 hours), the whole of the land overlying the mines was broken up or rifted, and the compressed air from the mines forced its way through the rocks, opening up lines of communication for the water to reach the mines almost continuously in small quantities. Since 1880, whenever the brine is pumped rather low, sudden inbursts of water occur and more destruction takes place. A large lake, fully 30 acres in area, and of great depth, now covers the old mines that were the scene of the 1880 inbursts (Fig. 1, Plate VIII.). This particular area is subject to the operation of all the causes of subsidence described, there is the ordinary brine subsidence, also the occurrence of old mines in the Upper Bed of salt, as well as the large abandoned mines in the Bottom Bed. The conjunction of all three causes has led to the extremely rapid sinking of the district lying to the north of Northwich, between Dunkirk, Marston and Wincham, and the forming of a very large and rapidly growing lake (Figs. 18, 19, and 20).

The history of the Northwich subsidences is well known. The first to be noticed were the collapsing mines in the Upper Bed of rock-salt. In the year 1750, a mine fell in close to the main street; this rock-pit hole remained for over a century and was known as the "Old Rock-pit Hole." It is now filled in and covered with property. In 1757, there is mention in an Act of Parliament of one recently fallen in. In 1759, one fell in and destroyed the river Weaver lock at Northwich. From this date, onward to the end of the eighteenth century, there are repeated records of the falling in of mines in the Top Bed of rock-salt.

The writer has located the sites of over 40 of these mines, and more than a dozen of them are covered completely by the lakes or "flashes," as they are called. About 20 of those old mines may be traced as rock-pit holes, the remainder have been filled in, leaving only the still existing mine at Marston, which is over the Marston old lower mine. This Marston lower mine was the first sunk to the Second Bed of rock-salt about the year 1781.

In almost every case, the mines in the Upper Bed of rock-salt,

as before pointed out were destroyed by water, which is the greatest enemy met with in salt-mining. It is not that the water is in such large quantities that it cannot be pumped down; but because it eats away the salt so rapidly that the pillars supporting the roofs are destroyed, especially those in the vicinity of the shaft, the weakest portion of the mine, and where the fresh water first comes into contact with the salt. The rock-salt in the shaft is also cut away so completely by the descending water that the overlying strata slip into the mine. Even when the shafts have been timbered, and puddle put behind the timbers, water finds its way down, and the salt behind the timbers is eaten away, leaving large cavities, which endanger the shaft (Fig. 11, Plate X.).

FIG. 19.—VIEW, TAKEN IN DECEMBER, 1880, OF SUBSIDENCE AT DUNKIRK, NEAR ASHTON'S WORKS, NOW (1900) COVERED BY MANY FEET OF WATER.

The writer met with a good instance a short time ago of the power of water to cut away rock-salt in one of the Bottom mines. Water had found its way down the shafts, and had covered the sole or floor of the mine, in the lowest portions, from a few inches to over 1 foot in depth. Wherever the water reached, the salt was eaten away, and the pillars were undercut to an extent varying from a few inches to nearly 1 foot in height, and penetrating from 1 foot or so, to the whole extent of the pillar. The writer had a rope passed under a pillar where the deepest water had stood. The rope was drawn completely under the pillar, and the whole

of the mass or pillar of salt, 36 feet square and 15 feet deep, was found to be suspended from the roof without any support. This mass of salt would weigh about 1,150 tons. It will easily be seen that if the water similarly reached the whole of the pillars in a mine the support of the roof would soon be destroyed (Fig. 4, Plate IX.).

Within the last two years, the most extensive subsidence now occurring (to which the writer will shortly refer) has reached some old Top mines, which were flooded or abandoned a century ago. The pillars not destroyed by the first inrush of water a century or more since are now being eaten away and acre after acre of the overlying land is being submerged.

As very few of the Top mines were under any of the house property of the district, only the land of the mine-owner was injured when they collapsed and a rock-pit hole full of water was left. No complaints were made, and no compensation for damage done was then asked for. The records of these sinkings can only be found in notes on old maps, or in minutes and resolutions of local authorities when highways were damaged.

The second kind of subsidences to appear were those caused by the pumping of brine from off the rock-head, that is the surface of the Upper Bed of rock-salt. These are by far the most serious and widespread, and from these the town of Northwich suffers so much damage.

The district within which the Top mines of rock-salt occur does not exceed 200 acres, and of this the cavities actually formed by the extraction of the rock-salt would probably not exceed 30 acres. The writer bases these figures on the shipments of rock-salt from the Top mines down the river Weaver, which did not exceed 2,000,000 tons, and this, at about 70,000 tons to the acre, would be just over 28 acres.

The area covered by the rock-salt beds, so far as proved, is less than 4 square miles, or say about 2,000 acres. The whole of the land over this area is not affected by subsidence, but as far as the Upper Bed of rock-salt extends it is liable to be injured, as there is not certainty as to where the fresh water may reach the rock-salt and find its way to the pumps. The extreme points showing subsidence may be included within 1,500 acres, while the very serious subsidences are all included within an area of 600 acres,

and the main part where buildings are affected is less than half of this (Fig. 1, Plate VIII.). It is extremely difficult to give very accurate figures, as there is not only the very gradual sinking barely perceptible over a large area in the course of a number of years: but the rapid sinking along what may be called brine-streams. It may be said that, like ordinary brooks and rivers, these brine-streams keep to a fairly defined course, but sometimes, probably owing to falls of earth, they seem to be dammed up and change their course, and rapid subsidence takes place where none had been known previously.

FIG. 20.—VIEW OF SUBSIDING LAND NEAR ASHTON'S WORKS, NOW (1900) UNDER WATER.

The most serious and dangerous subsidences are those connected with the defined streams, which cause deep troughs to form on the surface of the land. The property on either side of these troughs sinks towards the centre, the buildings tearing themselves away from the adjacent property on the outer edge of the sinkings and crushing into one another at the lowest part of the trough. Owing to causes rather difficult to understand, a sinking would seem to form round a centre where there is no brine-shaft or other known means for carrying away the water from the hollow made. As, however, the brine or water goes away, and the sinking extends very rapidly, there must be some connection with old valleys and rifts on the surface of the rock-salt. During the last few years,

one of these deep circular depressions has been forming amongst a number of houses that had been sinking very gradually for many years, and now property to the value of from £5,000 to £10,000 has been destroyed. In, and immediately adjacent to, one street alone more than 30 houses have been condemned as dangerous, and pulled down, whilst a large number of others will shortly have to be dealt with in the same way. It is over the course of these subsidences on the Top rock-salt that large holes have been formed in the streets and highways, destroying property, breaking gas-mains and water-mains, and deranging the sewerage of the district. Over these, also, have occurred the sinkings which on two occasions swallowed up horses standing in their stables, and barrels of beer in the cellar of an inn.

Owing to these subsidences, which show themselves first in small cracks in the buildings, and in doors and windows refusing to open or shut, a system of framework buildings has been allowed, so that when a building sinks it can be lifted by screw-jacks and put back to its original position (Figs. 14, 15, 21, 22 and 23). By degrees, the town is becoming one of framework buildings, and will, for England, be quite unique.

The manufacture of white salt had been carried on at Northwich, on what would now be called a very small scale, from the time of the Romans. After the river Weaver was made navigable (under the Act of 1721), which was not till about 1733, salt was sent down to Liverpool, and the manufacture increased. In 1735, about 8,000 tons were cleared down the Weaver; and this quantity had only increased to about 18,000 tons in 1760. About 1770, a decided improvement took place and 33,000 tons were shipped, by 1790 this had reached 52,000 tons; and 90,000 tons in 1800. It was during this last decade that the subsidences caused by brine pumping from the surface of the First Bed of rock-salt became apparent. By 1820, the shipments had only reached about 103,000 tons, owing to the Napoleonic war.

The very heavy duty of £30 a ton during the war was abolished in 1825, and by 1830 the shipments had reached 143,000 tons. The increase continued till 326,000 tons were sent down the Weaver in 1880, besides a large quantity sent away by rail, and a quantity of brine used in the chemical works.

From 1840 to 1870, in the Northwich district, at least 250,000 tons of salt per year were abstracted in brine from the surface of the Upper Bed of rock-salt. If this salt had been evenly removed from the whole 1,500 acres, within which area subsidences had been experienced, the surface would have been lowered 2 feet in the 30 years, or confining the calculation to the 600 acres where the great bulk of the subsidence occurred, there was sufficient salt abstracted in brine to have lowered the lesser area 5 feet. However, as by no means was the whole of the 600 acres affected, it will

FIG. 21.—VIEW SHOWING THE UNDERBUILDING OF HOUSES, AFTER LIFTING, IN CASTLE STREET, NORTHWICH.

be seen that some portions must have sunk a great deal more than 5 feet, and this was the case over the course of the brine-runs.

About 1870, the old mines were tapped and brine pumped from them, though there is still a good deal pumped from the surface of the Upper Bed of rock-salt, and the subsidences continue on a large scale.

It is pretty certain that not less than 25,000,000 tons of salt have been made in the Northwich district from brine pumped off the Upper Bed of rock-salt. This gives more than 6 feet in thickness over the 1,500 acres within which sinking occurs, or 15 feet

over the 600 acres where the bulk of the subsidences occur, and consequently, as the sinking is not evenly spread, much more than 15 feet in the worst sinking areas. As these calculations are all based on actual figures and are the very lowest fairly allowable, it is not surprising that the Northwich district has suffered so much.

In addition to the sinking caused by the mines in the Upper Bed of rock-salt, and the pumping of brine from the rock-head, there is the extension and intensifying of the subsidences by the pumping of brine from the abandoned mines in the Lower or Second Bed of rock-salt.

The Second Bed of rock-salt is from 80 to 90 feet thick and as the mines are all in the lowest 20 or 30 feet, there is between the bottom or sole of the mines in the Upper Bed of rock-salt and the roof of the mines in the Lower Bed, a thickness of from 90 to 100 feet of rock-salt and indurated marl (there being a bed of this latter from 27 to 30 feet thick between the two beds of salt). Where there are no Upper mines, the thickness of the salt, marls and drift above the roof of the Lower mines is, on the average, 300 feet.

It was at first thought that pillars, 15 feet square, at distances of 75 feet would sustain the roof. Soon, however, these showed signs of weakness, then 18 feet square was required in leases, and now pillars 24, 30 and 36 feet square are left. Where small pillars were left, the weight of the overlying salt and rock caused the pillars to split and crack and break to pieces, and the roof gradually "crept" down, until it neared or reached the sole, huge rifts or cracks showing in the roof. It was long before the "creeping" affected the surface, and when once water or weak brine found its way through the "rifts" mischief commenced. Although brine had been pumped out of these abandoned mines earlier, it was only upon a comparatively small scale until about 1870, when (owing to the almost entire exhaustion of the rock-head brine), pumping on an extensive scale commenced.

Occasionally as a mine was exhausted, it was connected with another, and so on until 8 or 10 mines, covering 60 to 70 acres, became connected. There are two groups of these connected mines, each fully 60 or 70 acres in area, and the pumping from them has been extensive and continuous.

As only a few mines had given way because of crushed pillars,

water could not enter most of them except by the shafts. The same water-trouble occurred as in the Upper mines, and the shafts of most of the mines were injured by the water running down them. After the abandonment of these mines as working mines, the shafts were neglected, and when the mines were pumped low, water entered and ate away the sides of the shafts and pillars and the surface commenced to sink.

In December, 1880, water broke into Platt's Hill mine on Dunkirk, which had been worked into adjacent abandoned mines con-

FIG. 22.—VIEW OF THE FRONT OF THE CROWN AND ANCHOR HOTEL, HIGH STREET, NORTHWICH, SHOWING THE LIFTING IN 1900.

taining brine. For many hours an enormous stream of water poured into the mine, several old overlying Top mines collapsed, and adjacent buildings were destroyed. The damage was enormous, and the area surrounding Platt's Hill mine was broken up in such a manner that when the pumping out of the group of mines with which Platt's Hill is connected was increased about 1893, the damage became greatly intensified, and now a lake of about 30 acres, varying in depth from a few feet to 100 feet or more about the shafts, exists and is daily extending.

It is on the borders of this lake that the most violent sinkings

are occurring, and in spite of several scores of thousands of tons of earth and stones and ballast having been put in (in the immediate vicinity of the old shafts) the sinking still continues.

In 1893, when the first sinking at the shafts occurred, the writer made a sketch and took a measurement of a hole and found that it was 90 feet long by 15 feet wide, the surface of the land being from 20 to 30 feet above the level of the neighbouring brook. To-day, this hole has become fully 5 acres in area, and notwithstanding the enormous quantities of ballast and rubbish continually being put in amounting from November 3, 1897, to March 31, 1900, to 168,000 tons, the depth over nearly the whole area is more than 50 feet. At one time the depth over the old shafts and near them was over 200 feet. At least 500,000 gallons of brine are pumped out of this group of mines daily. When the pumping has reduced the brine very considerably, a fresh inrush of water takes place, and this on passing through the overlying rock-salt eats it away, materially widening the access into the mines and making it more difficult to choke the hole again. It is fortunate that very few buildings are on this violently sinking land.*

None of the old abandoned mines filled with brine are under any portion of the town of Northwich. There are 4 mines, all dry, and working or workable, under portions of the town; but none of the subsidences now occurring are owing to them. The town of Northwich suffers entirely from the subsidence caused by pumping of brine from the rock-head. In two or three small areas, this subsidence may have been intensified in the past by the proximity of old mines in the Upper Bed of rock-salt abandoned or destroyed more than a century ago. When in the middle of this century the subsidence began to increase more rapidly, and the property of persons not engaged in the salt-trade suffered much injury, the question of obtaining compensation for this damage was raised.

In 1871, the Salt Chamber of Commerce addressed a letter to the Board of Trade asking them to take a report from one of their scientific and practical mining officers upon "the extraordinary phenomena occurring periodically in the salt-districts." The Board of Trade referred the letter to the Secretary of State,

* While writing, the water has burst into the Marston group of mines and raised the water-level in the shaft 66 feet—while the overlying lake, about 16 acres in area, has been lowered from 4 to 5 feet.

who directed Mr. Joseph Dickinson, one of H. M. inspectors of mines, to report, and in March, 1873, Mr. Dickinson presented a most valuable report dealing fully with the question in all its different phases. This report was presented to Parliament and ordered to be printed under the heading of *Salt Districts* (*Landslips*), and is entitled "Landslips in the Salt-districts."

Shortly after this report was issued, the owners of property suffering from brine-pumping commenced to agitate. Appeal was made by the local authorities to the Local Government Board,

FIG. 23.—VIEW OF THE REAR OF THE CROWN AND ANCHOR HOTEL, HIGH STREET, NORTHWICH, SHOWING THE LIFTING IN 1900.

and in 1881 a Bill was put forward in Parliament by the local authorities and injured property-owners jointly. It was most strenuously opposed by the salt-proprietors, and after an enquiry extending over 11 days before a Parliamentary Committee was thrown out. In 1891, another Bill was brought in and finally passed, enabling Compensation Boards to be formed in any subsiding districts, and empowering these boards to levy a rate annually of not exceeding 3d. on every 1,000 gallons of brine pumped, to form a fund for compensating owners of property injured by the pumping of brine.

This Act was put into force, and a Provisional Order obtained for the Northwich district in 1896, by which compensation is only paid to private property-owners; but all local authorities, gas-and-water companies, railway-and-canal companies, the trustees of the river Weaver, and all pumpers of brine, are excepted, and no compensation is paid to them.

In 1897, claims were made by the owners of 363 buildings amounting to over £27,000. Many of these claims being for damage occurring before the passing of the Act, were disallowed, but about £4,000 per year has been since paid and the claims are still numerous and heavy. A great deal of old property that was not worth spending much money on has been purchased and pulled down and new property is not allowed to be built on the sinking land.

LIST OF DRAWINGS ON PLATES VIII., IX. AND X.

Fig. 1.—Plan of the Town of Northwich and District, shewing the areas within which perceptible and serious subsidences have occurred.

Fig. 2.—East-and-west section of the Upper Bed of rock-salt passing through the Marston bore-hole.

Fig. 3.—North-and-south section of the Upper Bed of rock-salt passing through the Marston bore-hole.

Fig. 4.—Section shewing subsidences caused by pumping brine, and crushing of pillars in the Lower Bed of rock-salt.

Fig. 5.—"A Plan of a Field and Rock Pit, in Witton cum Twambrook, belonging to Nicholas Ashton, Esq., survey'd March, 1789, by J. Earl. Reference or Remarks: Area of each Pillar in the Rock Pit is 23½ Yards; the Content of the Whole 32 Pillars is 11¾ Perches; Depth of the Day Shaft is 41½ Yards; Depth of the Metal below that is 8¾ Yards and Depth of the Hollow, 11¾ Yards. Mr. Marshall's Pit in the Day Shaft at the nearest Distance from Mr. Ashton's Land is 12 Yards, and in the Sump Shaft, 14½ Yards."

Fig. 6.—"Plotted Plan of Messrs. Bournes and Co.'s Rock and White Salt Works, situate at Marston. Surveyed and dialled by Joseph Firth, 1814." "NOTA BENE: Parts marked *a*, show the Parts excavated since the 27th September, 1814, up to the 5th April, 1815. Parts marked *b* shew the extension of the Work from the 5th April, 1815, up to the 11th October, 1815. Parts marked *c* show the extension of the Work from the 11th October, 1815, up to the 24th January, 1816."

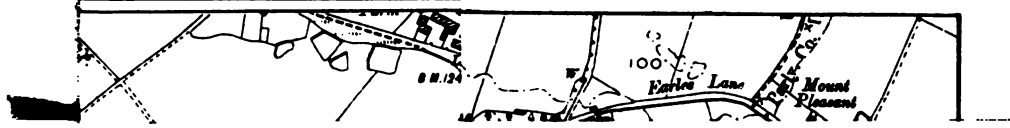
Fig. 7.—Section of a rock-pit hole.

Fig. 8.—"A Plan of Witton Brook in 1768."

Fig. 9.—Section of a mine in the Upper Bed of rock-salt.

Fig. 10.—Section of a mine in the Lower Bed of rock-salt.

Fig. 11.—Section of Rock Shaft, late Townsend's Shaft, Wincham.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Earles Lane
Mount Pleasant

Mr. J. GERRARD (H.M. Inspector of Mines) said that he had pleasure in moving a vote of thanks to Mr. Ward for his exceedingly interesting and valuable paper. With regard to the crushing of pillars, he would be glad to know what were the sizes of the pillars which were proved to be too small, and also the sizes of the pillars now being left. He believed that Mr. Ward was acquainted with the subsidence owing to which the old Duncrue pit was lost. Although some subsidences had been sudden, there had been apparently sufficient warning to enable the occupants of houses to get out.

Prof. EDWARD HULL, in seconding the vote of thanks, said that these subsidences and disturbances were very serious. The members had heard an account of the subsidences due to artificial causes similar to what had been going on for untold ages by natural processes and had given rise to the "meres" of Cheshire and Shropshire. The country was largely covered with marl, sands, gravels and clay, but underlying it was the Red Marl formation, which when sunk through was found to contain beds of salt. These "meres" undoubtedly owed their origin, as the late Mr. Ormerod was the first to recognize, to the dissolution of the rock-salt underlying tracks by water percolating and finding an outlet in springs. This process had being going on for ages, resulting in the formation of the "meres" or little lakes, and they were still being extended owing to the pumping operations near Northwich and elsewhere.

The PRESIDENT (Mr. H. C. Peake) said that it was difficult to draw an analogy between such gigantic subsidences as those mentioned in the paper, and the trivial subsidences with which they had to deal in coal-mining, but it seemed clear that there was a good deal to be learned as to the way in which buildings were affected, by studying underground conditions so far as they could be correlated with the surface-area and as shewing the effects upon buildings. It was a slight satisfaction, when he was working a thin seam, say, 4 feet thick at a depth of 1,000 or 1,500 feet under a village, to know that this could be done without material damage. The enormous underground cavities at Northwich, the result of so large an amount of material being removed, were out of all proportion to what occurred in an ordinary coal-mine. He was sure that the members would cordially approve of the vote of thanks which had been proposed.

The proposal was carried with acclamation.

Mr. T. WARD, in acknowledging the vote, said the pillars were 15 feet square, that became crushed, and were left at intervals of 75 feet. It was now the custom to leave pillars, 30 to 36 feet square, and the same distance apart. There had been no loss of life except animal life, from the subsidences. The subject was exceedingly interesting, more so to him, one of those who had the carrying out of an Act of Parliament, on a Compensation Board which had to deal with every claim for damage from subsidences.

The meeting was then adjourned until the following day.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON,
JUNE 15TH, 1900.

MR. H. C. PEAKE, PRESIDENT, IN THE CHAIR.

Mr. A. R. SAWYER's paper on "The Portuguese Manica Gold-field" was read as follows:—

THE PORTUGUESE MANICA GOLD-FIELD.

BY A. R. SAWYER.

I. INTRODUCTION.

This paper is based on notes gathered during a three months' stay in the Portuguese Manica gold-field, towards the end of 1899. The writer gathered much confidential information about the mines, which he is therefore unable to use.

II. GEOGRAPHY.

The Manica gold-field is situated in Portuguese territory between longitudes 32 degrees 40 minutes and 33 degrees east of Greenwich, and latitudes 18 degrees 48 minutes and 18 degrees 55 minutes south. It adjoins and is the eastern continuation of the Umtali gold-field situated in Rhodesia (Fig. 1, Plate XI.). The township of Macequece, which lies on the southern fringe of the gold-field is situated on the Salisbury (Rhodesia) and Beira railway, and is thus connected with the sea. This line will shortly have a 3½ feet gauge throughout. The gold-field is watered by the Revue river, with its affluents, the Zambusi, the Umhungwe (Yahunga or M'hongwe), the Yamalamba, the Chua, the Madzi, the Inhamazonga, the Musane, the Chimesi and the Menini rivers. The rivers all contain much water all the year round. The Umhungwe valley was until recently considered as belonging to the Chartered Company of British South Africa. The boundary, which has lately been finally settled, leaves the whole of this rich valley within Portuguese territory.

III. Topography.

The district is a mountainous one. It contains several high ridges trending from west to east, of which the two most prominent are the Hog's Back and the Venga. These ridges reach a height of from 4,000 feet to 5,550 feet (above sea-level), or 2,000 to 3,550 feet above the Revue river. Figs. 3, 4, 5, 6 and 7 give a general idea of the nature of the country, as regards hills, water-power and vegetation, and were photographed by Mr. P. D. Durell.

IV. Area.

The Manica gold-field, so far as at present known, extends 20 miles from the Rhodesian boundary to the east, and 9 miles on an average from north to south, thus comprising an area of 180 square miles.

V. Timber.

There is abundance of timber for mining purposes and for fuel in parts of this gold-field. Some of the trees on the slopes of the Venga and elsewhere are very large, and would make magnificent mining timber, of which the most suitable is redwood.

VI. Mining.

Although no doubt much alluvial gold has been obtained in ancient times, as evidenced by the numerous old alluvial workings, there are far fewer old reef-workings and these are far less extensive than many which the writer has seen in Rhodesia.

There has been much reef-prospecting in some parts in modern times, but the gold-field, as a whole, cannot be said so far to have been properly and systematically prospected throughout, as evidenced by certain rich finds, in the Chimesi valley, which were only discovered last year. There is, therefore, plenty of room for prospectors, and the recent and former finds are sufficiently encouraging to induce further work of that nature.

Alluvial gold is still found in the various river-beds, but now, in the writer's opinion, it can only be profitably worked on a very large scale, as is done in New Zealand and other places.

The following is a list of the more important reefs which have been or are being now worked to some extent:—In the Umhungwe valley, the Revue reef; in the Revue valley, the Pardy* and

* The Pardy reefs include the Guy Fawkes and associated reefs.

Quettehou reefs; and in the Chimesi valley, the Bragança and Richmond reefs.

Work has also been done (but not extensively) on other properties, as follows:—In the Umhungwe valley, the Eva, Mikado and S.G. syndicate claims; in the Musane valley, the Sheba claims; in the Chimesi valley, the Piddesley claims; on the western slope of Mount Venga, the Venga claims; in the Revue valley, the Birthday, Crœsus, Grand Ophir, Greenwood, Mac, MacHugh, Nines, Persimmon, Sirdar and Watford claims, and the Pay Rock claims, near the north-western boundary.

FIG. 3.—MESSRS. EVERITT AND DURELL PANNING NEAR THE BRAGANÇA CAMP.

Revue Reef.—In 1893, when the Umhungwe valley, in which the Revue reef is situated, was still considered to be part of the territory of the Chartered Company of British South Africa, the writer formed a very favourable opinion of this locality and described it in chapter iv. of his book on *The Gold-fields of Mashonaland*. No reef had actually been found at that time, but the prospects appeared to be good. The writer advised that a tunnel should be driven, but through the subsidence of the outcrop of the Revue reef, which was subsequently discovered where the writer had expected a reef to occur, the tunnel missed it. The reef is very uniform in thickness, and the walls are well defined.

It dips slightly to the south, and its strike, like that of the majority of reefs in this gold-field, is east and west. A thick well-defined and prominent bar of banded quartzite lies slightly to the south of the reef. The quartzite-bar and the reef are traceable eastwards and westwards.

Pardy Reefs.—The Pardy reefs, of which the Guy Fawkes is the most prominent, are situated 4 miles north of Macequece, on the northern side of the Revue river and not far from it. The reefs consist of ordinary quartz, mostly white, in a country-rock of chlorite-schist. The reef is very distinctly traced through the present workings, and varies much in thickness. It is lenticular, and its dip is nearly vertical. The mine is won by a tunnel down to the 300 feet level, and winzes connect the latter with the 400 feet level. The writer examined the workings in the 400 feet level, in which 330 feet are opened, and the reef, there, has a decided appearance of continuity in depth.

Quettehou Reefs.—The Quettehou reefs form, in the writer's opinion, the western extension of the Pardy reefs. The quartz is white, and the country-rock is talc or chlorite-schist.

Bragança Reefs.—The workings at the Bragança mine have exposed two reefs. One reef, which runs north and south, is probably an offshot of the second, a very thick reef with an east-and-west strike. These reefs, so far as exposed, are in more or less decomposed rock, and consist of veins and stringers of varying thicknesses of quartz within gold-bearing red clay.

VII. Geology.

The writer has made a large geological map of the Macequece gold-field, together with a collection of important rocks, with a view in some cases to further examination. Sections of some of these rocks were made as their character could not be ascertained by mere microscopical examination. The writer is indebted to Mr. T. Ryley for assistance in their description. The number of rock-specimens collected was 636, and 61 rock-sections were made.

(*a*) *Lithology.*—The rocks here described consist of:—(1) Acid igneous rocks; (2) intermediate igneous rocks, diorite, etc.; (3)

basic igneous rocks; (4) ultrabasic igneous rocks; (5) sedimentary rocks; and (6) metamorphic rocks.

1.—*Acid Igneous Rocks.*—The acid igneous rocks consist of granite, microgranite, graphic granite, granulite, felsite, quartz-felsite, felsite-breccia, quartz-porphyry and greisen.

Granite, as a plutonic rock, forms the foundation of the whole country; and with the exception of some of the basic igneous rocks and metamorphic rocks of igneous origin, the other rocks rest apparently upon it. It occasionally has a foliated or gneissoid character. Granite surrounds the metamorphic and sedimentary rocks which, generally speaking, form the gold-field. The granite and other rocks are traversed by basic igneous dykes. The mass of granite north and south of the gold-field does not present any special features.

Microgranite occurs, it is a rock with a fine-grained groundmass of felspar and quartz, containing, in some cases, conspicuous crystals of quartz-porphyry. The mica is usually muscovite, which occasionally occurs in very large flakes, notably in the Dororo valley. Actinolite sometimes occurs in it.

Graphic granite is also occasionally found.

Granite occurs amongst the metamorphic rocks, occasionally as a boss or apophysis, and such a boss occurs north of the Old Fort forming a conical hill. The mica here is a biotite.

Kaolinized felspar and kaolin occur in places.

Quartz-veins occur in the granite, notably in the north, where numerous white and mottled quartz-veins occur. The Venga reefs are quartz-veins, occurring in biotite-granite, partly decomposed. Some of the quartz, in a quartz-breccia, contains numerous crystals of pyrite. The quartz-reefs on and near the Birthday, Lion and Princess May claims occur in decomposed granite. Many of the quartz-reefs contain more or less gold, but so far none have been sufficiently proved to decide definitely about their prospects of values.

Granulite, a fine-grained granitic rock, in which all but quartz and felspar is invisible to the naked eye, occurs in places.

Greisen, consisting of quartz and mica, also occurs.

Felsites and rhyolites are very prominent in the Umhungwe valley, as well as in the Umtali valley, west of the watershed in Rhodesia. They form the northern ridges of the Umtali and part

FIG. 4.—VIEW OF THE UMHUNGWE FALLS, 100 FEET HIGH.

of the Umhungwe valleys, and also occur on the southern ridges. They are grey; have the appearance of felspathic mass; usually contain quartz-blebs, sometimes a few crystals of very much altered felspar, and are frequently sheared. They are occasionally decomposed and produce kaolin, which abounds in the Umhungwe valley, in which segregated quartz-veins occur: these are auriferous, and have been worked formerly, as evidenced by numerous old workings in the valley. These rocks are of volcanic origin, and are here probably in the form of sheets or solidified lava. They are of importance, owing to their forming through pressure sericite-schists, in connection with which rich gold-reefs occur, as will be explained later on.

A felsitic breccia occurs in the Revue valley in close proximity to the dolerite-dyke. It consists of fragments of various felsitic rocks of varying texture.

2.—*Intermediate Igneous Rocks.*—These rocks are very scarce, and occur mostly in and about the granite to the north. They are represented by diorite, consisting of plagioclase-felspars and hornblende. Porphyrite, an altered andesite, also occurs. These rocks are also very scarce in the Umtali valley, in Rhodesia, where they are represented by quartz-diorites.

3.—*Basic Igneous Rocks.*—These rocks are very abundant, and occur principally as dykes. Referring to some of these rocks, the writer stated in his book on *The Gold-fields of Mashonaland*:*

> At their junction with the schistose rocks, minerals have been developed in the latter by contact-metamorphism. These being the deep-seated rocks, they frequently contain the heavier metals in greater abundance, and it is in rocks in contact with them or derived from them that mineralized veins most frequently occur. The ore-particles and veinstone of which these veins are composed are derived from the neighbouring rocks, and have been deposited from solutions, not necessarily in fissures, but more often along certain cleavage- or foliation-planes, by interchange or replacement of the more soluble portions of the rock.

Gold is found in these rocks, and close to the watershed, amongst other reefs exposed, is a diabase-dyke containing auriferous quartz with visible gold, pyrite, and galena.

The basic igneous rocks are represented by gabbro, dolerite and diabase.

Gabbro is not frequently found. It contains granophyric quartz in one place.

The dolerite is ophitic, as is so usual in South Africa, and is frequently altered. Some mica-dolerite occurs.

The large majority of these rocks are diabase. A small quantity of quartz is occasionally found amongst them. Quartz-diabase also occurs.

Veins of calcite and pyrite occasionally occur in the diabases.

Saussurite-gabbro, an altered basic igneous rock, occurs.

A large dyke of actinolite diabase forms the watershed between the Umhungwe and Umtali rivers, namely, between the Portuguese and Rhodesian territories.

* Page 13.

4.—*Ultra-basic Rocks.*—These rocks, which occur pretty frequently, consist generally of serpentinized peridotite. It occurs in various shades of green. The texture ranges from fine to coarse. The structure is soft, hard, fibrous, banded and schistose through shearing.

5.—*Sedimentary Rocks.*—These consist of sandstone, conglomerates, breccia and clay-slates.

The conglomerates, breccias, some of the sandstones, and a few clay-slates are closely associated with similar metamorphic rocks of sedimentary origin. As these will be dealt with under the

FIG. 5.—VIEW OF THE UMHUNGWE VALLEY.

heading of metamorphic rocks, the writer will only state here that these sandstones are friable, fine-grained, ferruginous, banded, white, yellow-stained with oxide of iron, and occasionally micaceous. They sometimes contain talc and visible gold.

Fine-grained white sandstone occurs in large quantities in the eastern part of the gold-field, and forms the larger portion of the prominent hills which the writer has called the "Twins."

Calcareous sandstone occurs at the extreme west of the gold-field, on the Musane river. Yellow friable sandstone occurs in the Chimesi valley on the Piddesley claims. It is there associated with ferruginous quartz-conglomerate and sericite-schist.

The conglomerates and breccias contain pebbles of sandstone, quartz and quartzite, the matrix being sandstone.

Purple clay-slates occur on the Hog's Back and on the Venga Range in close proximity to the banded quartzites to be described later.

Clay-slate, yielding in places very good slates occur on the southern slope of Mount Venga.

6.—*Metamorphic Rocks.*—These form the greater part of the rocks of the gold-field. They have either an igneous or sedimentary origin which is not always apparent. Those of igneous origin are: Talc-schists, grey, green, and white, soft, hard, spongy, indurated (whetstone), banded, contorted, sheared, ferruginous, calcareous, fine-grained, with ferruginous and quartz "eyes," with crystals of selenite, andalusite, pyrite, ochreous material (very light), and with limonite, calcite and quartz-veins. Very prominent cleavage has been imposed upon these schists by lateral pressure at the eastern end of the gold-field. Its direction is from north to south and its dip is to the east in three large detached portions. Large slabs jut out with a regularity which gives them the appearance of "tombstones" similarly to those of the Dwyka Conglomerate, near Prince Albert in Cape Colony. At another place, the cleavage is north-west and south-east, and the dip south-westerly.

Talc-rock, fine-grained, crystalline, and green; quartz-talc rock; and quartzose talc-schist, fine-grained, hard, ferruginous, and dark grey occur in many places. Tremolite-rock and schist with occasional kaolinized felspar: talc-tremolite rock; actinolite-schist; and horneblende-schist, all more or less fine-grained, are well represented.

Actinolite-epidote schist with garnets occurs north of the "Twins."

Chlorite-schist occurs near the Crow's Nest on the Hog's Back; it forms the country-rock of the Guy Fawkes and other reefs along the same ridge. Chlorite-rock occurs near Dillon Camp and chlorite quartz-schist in several places.

Decomposed peridotite and altered serpentine-rocks also occur.

A prominent ridge of mica-schist, consisting of alternating bands of granular quartz and dark mica, with veins of white quartz, occurs near Mount Dadsi, a point north-east of the gold-field.

Micaceous quartz-schist occurs amongst granite.

Gneiss also occurs.

Laterite (decomposed dolerite) occurs near a dyke.

Sericite-schist occurs frequently in the Umhungwe and in the Chimesi valleys. It is ferruginous in part, and contains crystals of gypsum. Reference has been made to these schists above, and it is remarkable that some of the best or most promising reefs, like the Revue and the Piddesley, occur in close association with them. On the Piddesley claims in the Chimesi valley, they occur at the edge of the northern mass of granite and much gold appears to be associated with them.

FIG. 6.—VIEW OF THE UMHUNGWE VALLEY, WITH MOUNT VENGA IN THE DISTANCE.

Quartz-sericite schist is also frequent in its occurrence, as, for instance, south of Dillon Camp, adjoining the southern granite-mass.

Metamorphic rocks of sedimentary origin consist of sandstone, quartzite, breccia, conglomerate, grit, limestone, and quartz-schist. Some of these rocks, such as the conglomerates, breccias and some sandstones, have been alluded to above under the heading of sedimentary rocks. Here, these rocks have been altered, sheared and crushed, although their origin is still quite apparent.

These rocks, with their sedimentary prototypes, form prominent

outcrops. They are of importance owing to their occurrence near gold-reefs, such as the Revue, Quettehou, Guy Fawkes, Persimmon, and others. The sandstone is ferruginous and banded, usually with fine bands of limonite. The quartzite is white, black, milky, fine and coarse-grained, saccharoidal, ferruginous, spongy, and banded.

The banded quartzites consist of alternating bands of limonite, magnetite and white quartzite, with at times some chalcedony. They form very characteristic features and landmarks in the gold-field. These limonite-lamellæ vary in thickness from that of a sheet of paper, in which case they abound, to the thickness of 1 inch. The rock is often crumpled and occurs invariably with the lamellæ in a vertical position. These have in part a lenticular form or end abruptly. Numerous old workings occur along their outcrops, but whether the workers were in search of gold or iron is not apparent. There is no doubt that iron was worked here by the ancients, as proved by round bars of melted iron still to be found near these workings, and these quartzites are so rich in iron in places that they would lend themselves to iron-manufacture.

Closely connected with these quartzites, occur certain breccias and conglomerates in close apparent relation with the quartzites. They are mostly sheared and contain quartz, quartzite, and occasionally fragments of sandstone, all these occurring as angular and subangular and rounded pebbles. Some of the pebbles are composed of banded quartzite similar to that just described, and others of decomposed basic rocks and felsite.

Near the Guy Fawkes reef, and in other places, the matrix consists of a chloritic groundmass, in which are quartz-blebs, with included pebbles of banded quartzite, some pebbles being the size of a man's head.

Quartzite-veins also occur. In depth, below the oxidized zone, pyrite replaces limonite and occurs frequently. Chlorite-schist, with included pebbles of banded quartzite, the pebbles being flat, rounded and up to 10 inches long, occurs on the top of the Hog's Back (Fig. 2, Plate XI.).

These conglomerates and breccias are very thick in places. They resemble in part the well-known Dwyka Conglomerate; at other places, and particularly at Mount Chiromiro, and also near the Richmond claims, they are undistinguishable from some of the

Witwatersrand bankets. Though this similarity is remarkable, the writer does not wish it to be inferred that he considers these conglomerates to be of the same age as the banket-beds of the Rand. Whereas the former are probably of pre-Cambrian age, his opinion always has been that the latter are of Devonian age.

There are also distinct conglomerate-beds equally resembling banket beds in the Chimesi valley on the Piddesley and other claims. These conglomerates are so similar to some of the bankets of the Johannesburg Main Reef Series that it would be hard to distinguish them. These conglomerates are not associated in this locality with banded quartzite, but with sericite-schist, yellow and red sandstone, and talcose sandstone. There are several old workings on these claims, and though no definite reef had been located, the ground about them was rich in gold in many places.

Bands and veins of chlorite and talc occur generally in the conglomerates and breccias.

Calcareous quartzite occurs with and without pyrite, on the Sheba claims.

Crystalline limestone occurs in very small quantities on the Piddesley claims and on the Crœsus claims.

The writer discovered, between two beds of conglomerate, a rather large quantity of dark grey crystalline limestone resembling the "Elephant Rock" of the Transvaal, and containing quartz-veins, close to the Chiromiro peak.

Ottrelite-schist occurs in places.

Quartz-schist with ferruginous patches, usually fine-grained, is not infrequent.

Metamorphic rocks whose origin is not quite apparent, and which occur in this gold-field, comprise: Talcose slate, usually green: quartz-rock, with occasionally a small amount of calcite; quartzite, with veins of green talc; quartz-chlorite schist; talcose quartz-conglomerate; talcose sandstone; talcose breccia; talcose quartz-schist; talcose conglomerate, a prominent outcrop occurring close to the Dillon Camp, wherein the pebbles and matrix are both talcose. Sheared quartz-breccia, interlaminated with chlorite knotted-schist (knotenschiefer), occurs south of the Piddesley claims. Tremolite quartz-schist, knotted talcose-schist with actinolite, and micaceous quartz-schist also occur.

(*b*) *Structural.*—The sedimentary rocks and the metamorphic

rocks of sedimentary origin are, so to speak, stratified amongst metamorphic rocks of igneous origin. Their trend is from east to west, and their dip is practically vertical. Their most conspicuous member, as already stated, is banded quartzite, which occurs often on elevated positions.

The parallelism of their plane of stratification with the cleavage and foliation-planes of rocks of igneous origin like talc-schists is difficult of explanation. It is also difficult to understand the origin of rocks like the chlorite-schist conglomerate, the matrix of which is undoubtedly of igneous origin, whilst the pebbles point to a sedimentary one.

FIG. 7.—VIEW OF THE NORTHERN SIDE OF MOUNT VENGA.

These sedimentary rocks are traversed by dykes of dolerite and diabase: these usually have a north-to-south direction and cause displacements, the largest of which appears to have been at the eastern end of the Hog's Back, where the banded quartzites forming the backbone of the Hog's Back appear to have been thrown to the north, as far as the Quettehou and Ophir claims, whence they continue in an easterly direction past the Guy Fawkes claims.

Talc-schists and talc-rocks predominate amongst the metamorphic rocks of basic igneous origin. As already pointed out,

these have in places a distinctive cleavage running from north to south.

Though difficult to decide without prolonged investigation, it appears pretty certain that "bosses" of igneous rocks occur, and that the peak of biotite-granite on the southern slope of the Venga mountain is one.

(*c*) *Minerals.*—The minerals which occur in the gold-field are: Galena, pyromorphite, chromate of lead (crocoisite), cuprite, malachite, azurite, and those already mentioned.

The copper-ores occur at the south western corner of the gold-field, south of Dillon Camp, and appear to indicate the presence of a yet undiscovered reef. The amount and quality of the ore found as "float" in the locality would justify an expenditure to locate the reef.

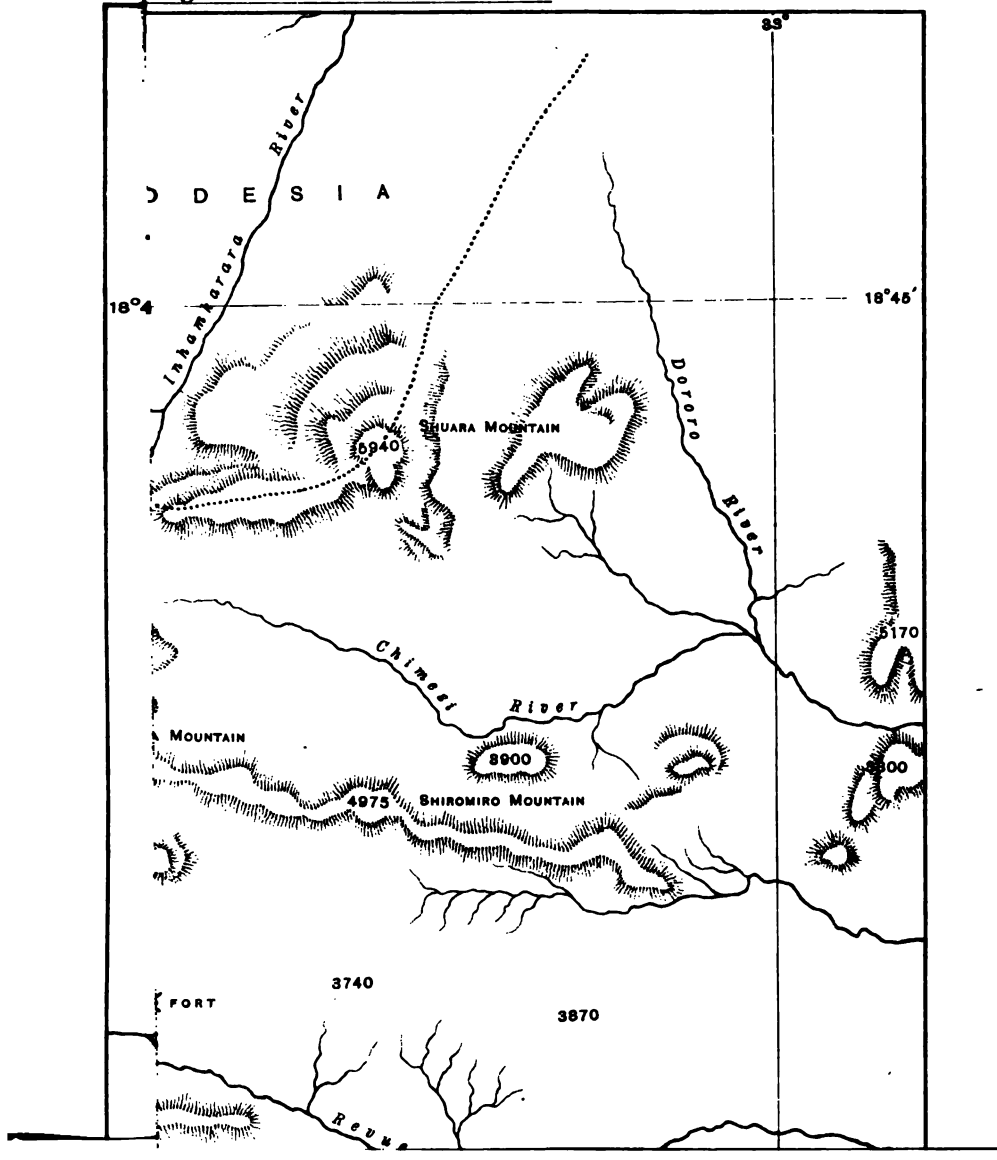
A light ochreous-looking mineral occurs on the Piddesley claims. A large quantity of a mineral similar in appearance occurs on the Sheba claims, which gives the dump at the mouth of the tunnel the appearance of a colliery pit-heap. This mineral has the appearance of an organic compound belonging to the hydrocarbon group, but this could only be determined by chemical analysis.

The writer has located graphite-schist on the southern slope of the Venga mountain, which is largely impregnated with graphite.

The PRESIDENT (Mr. H. C. Peake) moved a vote of thanks to Mr. A. R. Sawyer for his interesting paper, and the motion was cordially approved.

Mr. F. O. SOLOMON's paper on "The Feeding of Horses, with Special Reference to Colliery Studs" was read as follows:—

The ...tuguese Manica Gold-field."



THE FEEDING OF HORSES, WITH SPECIAL REFERENCE TO COLLIERY STUDS.

By F. O. SOLOMON, F.H.A.S., F.C.S.

Introduction.

The feeding-rations now adopted for horses, as well as those for other domesticated animals, are largely the outcome of many years of practical experience, and one has only to read the records of the diets employed for and the cost of maintenance of such large studs of horses as those comprising tram, omnibus and colliery stables to realize that vast sums of money have been expended in furnishing the information required. Such records also enable one to appreciate the enormous benefit which the owners of town and colliery studs have derived from the low prices of agricultural produce and the introduction into our markets of foreign grain.

During the past half-century, numerous feeding experiments with horses have been conducted, chiefly upon the Continent, but also to some extent in this country. These investigations have been chiefly concerned (1) with the quantity of food required by horses of a given size for a given amount of work, (2) with the digestibility of the ingredients of the various foodstuffs, and (3) with the correct apportionment of the various nutrient constituents contained in the foods. By the help of the results of these experiments it appears to be quite possible to arrange feeding-rations with sufficient accuracy for all practical purposes—that is, to provide rations which will supply a stud of horses with adequate and correctly proportioned food-material. The data available would also facilitate the drawing of comparisons between the various foods with regard to their nutritive values, and full advantage may be taken of the fluctuations which occur from time to time in the market prices of the foods. It would obviously be an advantage to have a system whereby a stable-manager might know how one food or mixture of foods could be substituted for another without

altering the nutritive value of the diet as a whole, as such changes are sometimes necessary as much for the well-being and health of the stud as for the owner's pocket.

Composition of Horse Foods.

It will perhaps be advisable in the first instance to enquire briefly into the general composition of foodstuffs. The accompanying arrangement illustrates roughly the component parts of corn, hay or any other food :—

- Foodstuff
  - Water
  - Dry matter
    - Nitrogenous principles
      - Albuminoids (proteids)
      - Amides, etc.
    - Non-nitrogenous principles
      - Carbohydrates
      - Fats and oils
      - Fibre
      - Mineral salts (ash)

Commencing from the left-hand, it will be seen that foodstuffs consist primarily of water and dry matter, and, when it is stated that an animal requires a given amount of "dry matter," the moisture existing in the foods is entirely eliminated from the calculations. The total dry matter is next seen to consist of nitrogenous principles and non-nitrogenous principles, and these may be again subdivided into their component parts as indicated.

Albuminoids.—The albuminoids or proteids are the true flesh- or muscle-formers, and are sometimes termed the "essential" or "indispensable" food ingredients, because without them life could not be sustained. They contain nitrogen (usually to the extent of about 15½ per cent.) for the construction and repair of animal tissue, and, by combustion in the body, their carbon, which is present to the extent of about 50 per cent., is utilized to maintain the heat of the body and to supply mechanical force. Beyond this, the albuminoids afford substance for the development of fat, but this is only when consumed in excessive quantity and probably is not in any case an important consideration in horse-feeding.

Amides.—The amides, although containing nitrogen, are not considered in the light of flesh-formers. They appear to be heat-producers, and therefore serve the same purpose in the body as the carbohydrates (starch, sugar, etc.). In heat-producing capacity,

however, the amides possess only about half the value of the carbohydrates weight for weight, and as they (the amides) are not contained in appreciable quantities in most horse-diets their presence may be here neglected.

Carbohydrates.—The carbohydrates, chiefly starch and to a lesser extent cellulose,* make up considerably the largest bulk of feeding material in all horse-foods, and must be looked upon as the chief heat-forming elements, as the fats, which have also the same property, are represented in horse-diets in comparatively small quantities. The chief function of the carbohydrates is to supply heat and mechanical force and when fed to excess they are also capable of producing animal fat.

Fats.—Fats do not enter at all largely into the composition of horse-foods. Oats and maize are the richest in this respect, and apparently the horse is almost as capable of digesting the fats in these foods as a ruminating animal. The fats are extremely potent heat-producers, and weight for weight are considered nearly 2½ (2·3 accurately) times as valuable for this purpose as the carbohydrates. A pound of pure fat would therefore produce as much heat in the body as nearly 2½ pounds of pure starch or sugar.

Fibre.—The fibre consists mainly of cellulose, and when capable of being digested may be considered as a carbohydrate, though digested cellulose is a somewhat less potent heat-former than starch or sugar. Of the commonly used horse-foods, it is present in the largest quantities in hay and oats, which contain about 25 per cent. and 10 per cent. of fibre respectively.

Mineral Matter.—Mineral matter, although performing an indispensable function in animal nutrition, may be neglected in calculating diets for horses, as it is usually present in sufficient quantities in all well-regulated rations. A few remarks will be made upon this subject later on.

Digestibility of Foods by Horses.

It is obvious that the value of a food depends greatly upon the facility with which its ingredients can be digested and assimilated

* Another very important carbohydrate is sugar, but it is not contained to any extent in common horse-foods.

by the animals consuming it. For the purpose of calculating feeding-rations any table giving the chemical composition of foods would be of little value, unless the matter of digestibility were taken into account.

TABLE I.—SHOWING THE AVERAGE PERCENTAGE OF DRY MATTER, AVERAGE PERCENTAGE OF DIGESTIBLE NUTRIENTS, ETC., IN HORSE-FOODS (APPLICABLE ONLY TO HORSES).*

Foods.	Average Quantity of Dry Matter.	Average Digestible Nutrients.			Albuminoid Ratio.	Average Weight per Bushel.
		Albuminoids.	Carbohydrates.	Fats.		
	Per cent.	Per cent.	Per cent.	Per cent.		Pounds.
Hay (clover)† ...	84	5·2	32·5	0·75	1 : 6·6	...
Hay (meadow)...	84	4·0	32·5	0·60	1 : 8·5	—
Pasture grass ..	25	1·8	11·0	0·12	1 : 6 3	—
Oats (crushed) ..	87	8·5	45·0	4·00	1 : 6·4	38 to 42
Beans	86	19·6	49·2	0 70	1 : 2·6	63 to 65
Peas	86	17·5	53 5	0·80	1 : 3·2	63 to 65
Maize	88	7·3	68·0	3·70	1 : 10·5	60
Barley	86	6·9	61·3	1·32	1 : 9·3	54 to 56
Bran	87	8·9	44·5	1·20	1 : 5·3	28
Gram (Bengal)‡..	?	12·0	57·0	?	1 : 4·8	?

* Adapted mainly from the average analyses of food stuffs in *The Chemistry of the Farm*, by Prof. R. Warington, F.R.S.

† The total carbohydrates in clover and meadow-hay are 36½ and 43 per cent. respectively; but the horse is apparently able to digest clover-hay better than meadow-hay, and the percentage of digestible carbohydrates seems to be about alike in the two cases.

‡ No digestion-experiments appear to have been carried out with this food: the figures here given assume the same digestive co-efficients as in the case of beans.

In Table I. an attempt has been made, with the help of available experimental results, to give the percentage of digestible nutrients in average samples of all the common horse-foods; the figures are applicable only to horses, as ruminating animals are found to yield different digestive co-efficients. The figures relating to albuminoids are intended to represent the percentage of digestible true proteid matter, that is exclusive of amides and other non-flesh-forming nitrogenous substances. The carbohydrates include digestible fibre (cellulose) as well as starch. In the first column of Table I. will be found the average percentage of total dry matter in the various foods, data which will be necessary for calculating the quantities of food required for specific purposes. Of the feeding-materials mentioned in Table I., hay is no doubt the most subject to variation in composition. Meadow-hay of exceptionally fine quality might, for instance, contain as much as 6 per cent. of digestible albuminoids, whilst other samples, which are ill-secured and composed of

poorer herbage, might contain less than half this quantity. Of the different descriptions of grain, oats are the most variable, their composition and digestibility depending considerably upon the proportion of husk.

Albuminoid Ratio.—This term signifies the proportion which the digestible true flesh-formers (albuminoids) bears to the digestible carbonaceous principles (carbohydrates and fats). In calculating the albuminoid ratio, the carbohydrates and fats are brought to the same denomination by multiplying the latter by 2·3, the product is added to the carbohydrates, and the sum is divided by the amount of albuminoids. Thus average oats are seen from Table I. to contain 8·5 per cent. of digestible albuminoids, 45 per cent. of digestible carbohydrates, and 4 per cent. of digestible fat. $[(4 \times 2{\cdot}3) + 45] \div 8{\cdot}5 = 6{\cdot}38$ nearly. The ratio of digestible albuminoids to digestible heat-producers is therefore approximately 1 to 6·4. The albuminoid ratio of an entire feeding ration is calculated by the same method, and it will be found that the ratios of different studs vary from 1 to 6 to 1 to 8, the average for horses in work being about 1 to 7. The wider ratios (that is 1 to 8 or over) are only recognized in the case of unemployed horses, or those working always at a walking pace. For trotting horses in trams and omnibuses, for colliery-horses and for heavy horses travelling upon the roads, 7 of heat-producing elements to 1 of flesh-forming may be considered the correct proportion to adopt.

Quantity of Food Required.

The food-requirements of horses are of course partly dependent upon the physiological characteristics of the animals themselves, as some horses will assimilate a given quantity of nutriment more thoroughly than others. But a far more important matter is the amount of work that the animals are called upon to do and the manner in which they are permitted to do it. The more quickly work is performed the harder it becomes, and the more sustenance is required by the animal. Prof. Warington writes* in reference to some French experiments:—

A horse walking 12½ miles a day was kept in condition with a daily ration of 19·4 pounds of hay, while a ration of 24 pounds of hay was insufficient when the

* *The Chemistry of the Farm.*

same distance was done trotting. A horse walking the above distance and dragging a load (additional work, 1,943 foot-tons) was sufficiently nourished by a ration of 26·4 pounds of hay; but a daily ration of 32·6 pounds (all that the horse would eat) was not enough to maintain the horse's weight when the same work was done trotting. When the horse is trotting, the frequency of the pulse, and consequently the internal work performed by the heart, is much increased. The horse, when trotting or galloping, also lifts his own weight at each step, but allows it to fall again—the result appearing only as heat. The temperature of the horse rises with exertion and much heat is lost by the evaporation of water through the skin and lungs. The horse at rest evaporated 6·4 pounds of water per day; when walking, 8·6 pounds; at work walking, 12·7 pounds; trotting, 13·4 pounds; at work trotting, 20·6 pounds. It follows, of course, that a horse requires more water when at work.

To take the case of a horse covering 12 miles a day, the work would be accomplished in about 1½ hours trotting, or in about 3½ to 4 hours walking. It would appear that an animal trotting 1½ hours per day may actually be employing much more physical energy than if he worked 3½ to 4 hours per day at a walking pace.

Colliery-horses have frequently three severe elements to fight against, namely, a rapid pace, long hours, and heavy gradients, and with these three conditions operating together they are, probably by common consent, the hardest worked animals in the country. The severity of the strain may be, and sometimes is, greatly mitigated by changing the animals at the different pit-workings; and in this way a horse that has had to work on a heavy gradient for some time, and as a consequence has lost condition, is allowed an alternate period on a more level surface, his place being taken by another animal whose previous work has been lighter. But in any case the work is distinctly hard, and therefore the feeding must be "hard" too.

Seeing, then, that the quantity of food required is dependent upon such varying circumstances, the following estimates must be looked upon as approximately correct for a number of horses in average work but not applicable to single individuals under more or less exceptional conditions of employment.

Prof. Emil von Wolff, of Hohenheim, considers from the results of experiments that farm-horses in average work require about 21 pounds of dry matter in their food per day per 1,000 pounds weight of animal. The weight of farm-horses of course varies considerably, the limits of variation being probably from 11 cwts. up to 18 cwts., or in exceptional cases even higher. The average may, however, be accepted approximately as 12½ to

13 cwts., say 1,430 pounds, in which case the animals would require just 30 pounds of dry substance per head per day. Such an amount of dry feeding material would be furnished by, say, 1 stone of oats and 1½ stones of hay per day. In the absence of direct experiment, it is not always an easy matter in this country to obtain accurate information regarding the amount of food required by horses engaged at farm work, because as a rule the bulky fodders like hay and oat straw are given *ad libitum*, and few farmers can supply a reliable estimate of the quantities of these consumed. From the particulars available, however, it would seem that an allowance of 30 pounds of dry matter is more than sufficient for an ordinary agricultural horse, and that his usual consumption would be more accurately represented by 26 or 27 pounds of dry substance per day, an amount which would be furnished by about 30 pounds of hay and corn.

TABLE II.—RATIONS FOR FARM-HORSES.

Description of Food.	No. 1.			No. 2.			No. 3.		
	Allowance per Horse.		Weight of the Ration.	Allowance per Horse.		Weight of the Ration.	Allowance per Horse.		Weight of the Ration.
	Per Week.	Per Day.		Per Week.	Per Day.		Per Week.	Per Day.	
	Stones	Pounds.	Per cent	Stones.	Pounds.	Per cent.	Stones.	Pounds.	Per cent
Hay... ...	10	20	62	9	18	56	6	12	37
Oat-straw ...	—	—	—	—	—	—	2½	5	15
Oats	6	12	38	6	12	38	3	6	19
Maize ...	—	—	—	—	—	—	3	6	19
Beans ...	—	—	—	1	2	6	1½	3	10
Total Food Consumed	16	32	100	16	32	100	16	32	100
Amount of Dry Matter	—	27½	—	—	27½	—	—	27½	—
Digestible Nutrients in daily food—									
Albuminoids	—	1·92	—	—	2·22	—	—	2·13	—
Carbohydrates ...	—	11·90	—	—	12·23	—	—	13·41	—
Fat	—	0·62	—	—	0·62	—	—	0·56	—
Albuminoid—Ratio (approximate)*	1 : 7			1 : 6			1 : 7		

* The method of determining these ratios is shown in Table III., and in text.

In Table II. are given three examples of farm-horse rations, each supplying over 27 pounds of dry substance, which may be con-

sidered amply sufficient for the average requirements of this kind of horse. In the lower part of the table are given the quantities of nutritive ingredients contained in these rations; it will be observed that Nos. 2 and 3 rations are considerably more nutritious than No. 1, although all furnish the same amount of total dry matter. Of the three examples given, No. 3 ration is probably the best, as well as being the cheapest.

Trotting horses working in trams, omnibuses, tradesmen's carts, etc., and probably also colliery-animals, will be found to require about 24 or 25 pounds of dry matter per 1,000 pounds weight per day. The writer has recently made inquiry into the rations adopted by some of the large tram and omnibus companies, and in one case, where a stud of 400 to 500 horses is maintained, 20 representative animals from the stables were placed upon the weighbridge. A greater number would have been weighed, but it was found that the variations in weight were so small that a score would be sufficient for the purpose. The average weight of the horses composing this stud, allowing for shoes and headstall, may be pretty accurately placed at 1,100 pounds. Table III. gives the feeding-ration adopted in this case, with the albuminoid ratio fully worked out from the data given in Table I.

TABLE III.

Food.	Amount consumed per Head per Day.	Dry Substance in Foods (approx.).	Quantities of Dry Substance in Foods.	Digestible Nutrients in Foods.			Quantity of Digestible Nutrients in Diet.		
				Albuminoids.	Carbohydrates	Fat.	Albuminoids.	Carbohydrates	Fat.
	Pounds.	Per cent.	Pounds.	Per cent	Per cent	Per cent	Pounds	Pounds	Pounds
Maize ..	0	87	8·70	7·3	68·0	3·7	0·73	6·80	0·37
Oats ...	4	87	3·48	8·5	45·0	4·0	0·34	1.80	0·16
Beans	2	87	1·74	19·6	49·3	0·7	0·39	0·98	0·01
Hay * .	15	85	12·75	4·6	32·5	0·6	0·69	4·87	0·09
Totals	31	--	26·67	—	—	—	2·15	14·45	0 63

* A mixture of clover and meadow-hay.

The albuminoid ratio will be $[(0{\cdot}63 \times 2{\cdot}3) + 14{\cdot}45] \div 2{\cdot}15 = 7{\cdot}3$.

Considering the corn and the hay as containing 87 per cent. and 85 per cent. of dry matter respectively, the quantity of dry substance per 1,100 pounds weight of animal is seen to be 26·67 pounds, which would be about 24½ pounds of dry matter per 1,000 pounds weight of animal. In a valuable contribution to the *Transactions* of the Highland and Agricultural Society for 1895,

Sir J. Lawes and Sir J. H. Gilbert give the average rations employed by the General Omnibus Company of Paris, whose stud numbers about 13,000 animals, weighing from 1,200 pounds to 1,240 pounds per head. Taking the average for the three years 1885 to 1887, the consumption of dry matter per head per day was just about 30½ pounds, which would represent about 25 pounds of dry substance per 1,000 pounds weight of animal.

The albuminoid ratio of the diet given in Table III. is 1 to 7·3. It seems from similar calculations of other diets that where the ratio is narrower (say 1 to 6 or even 1 to 5½), the amount of dry matter required is somewhat less, but probably in practice it is found more economical to adhere to a ratio of about 1 to 7, and consume a proportionately larger amount of food. As a rule, it may be said with regard to all animal diets that the narrower the ratio the more expensive is a given weight of food. It was formerly considered that the exercise of force created a sensible demand upon the nitrogenous food-constituents, and that the amount of work performed would be largely dependent upon the supply of muscle-forming matter in the food. Sir J. Lawes and Sir J. H. Gilbert have, however, established that the demand is more for the digestible non-nitrogenous ingredients (starch, etc.) than for the specially flesh-forming foods.

TABLE IV.—RATIONS FOR COLLIERY-HORSES.

Description of Food.	For Horses				For Ponies.			
	16 and 17 Hands high.		About 14 Hands high.		About 12 Hands high.		About 10 Hands high.	
	Per Head. per Day.	Weight of the Mixture.	Per Head. per Day.	Weight of the Mixture.	Per Head. per Day.	Weight of the Mixture.	Per Head. per Day.	Weight of the Mixture.
	Pounds.	Per cent	Pounds.	Per cent.	Pounds.	Per cent	Pounds.	Per cent.
Hay	12	38	8	37	6	36½	4½	37½
Oats	5½	17½	6	27	3	18	2	16½
Beans	3	9½	—	—	1¼	9	—	—
Peas	—	—	2	9	—	—	1½	12½
Maize	11	35	6	27	6	36½	4	33½
Total Food consumed.	31½	100	22	100	16½	100	12	100
Amount of Dry Matter.	27	—	19	—	14	—	10½	—
Approximate Albuminoid Ratio.	1 : 7·1		1 : 7		1 : 7·1		1 : 7	

Rations for Colliery-horses.

In Table IV. are given a few examples of rations for colliery-studs adapted from those in actual practice. It will be seen that for horses in average pit-work, the amount of dry matter required per animal per day varies from about 10 or 11 pounds in the case of the smallest Shetland ponies to about 27 or 28 pounds in the case of big horses standing over 16 hands in height.

As a general rule, it is found economical to employ chopped hay to the extent of about 35 to 40 per cent. by weight of the mixture, the remainder being bruised or cracked corn. A glance at the columns headed "weight of the mixture, per cent.," will show that the proportionate amounts in which the different descriptions of food enter into the composition of the rations differ to a comparatively small extent. Roughly speaking. the ingredients of the diet are supplied in about the following proportions:—

Hay,	about 35 to 40	per cent.	by weight	of the mixture
Oats.	,, 17 to 25	,,	,,	,,
Pulse,	,, 9 to 12	,,	,,	,,
Maize,	,, 27 to 35	,,	,,	,,

The albuminoid ratios are about 1 to 7 for colliery-horses in work, but for horses not in actual work or engaged only at light work at the surface, a ratio of about 1 to 8 is found serviceable. Other things being equal, the wider ratios are usually cheaper, as they allow of a larger proportion of maize in the diet.

Substitution of Foods.

In substituting one food or mixture of foods for another, two points must be considered: (1) To maintain the correct proportion between the flesh- and heat-forming constituents, and (2) to blend the foods so that the whole diet may be neither too laxative nor too constipating. This latter point becomes the more important in the case of very hard-worked horses such as those engaged at pit-work, but fortunately it is not a difficult matter to regulate, because, as a rule, the very starchy foods, such as maize and barley, are laxative in their nature, whilst the foods which would naturally be added to "narrow" the albuminoid ratio, such as beans and peas, have a tendency in the opposite direction. Bran is somewhat an exception to this rule, as its ratio is fairly narrow (about 1 to 5·3), whilst its action upon the bowels is laxa-

tive. If, therefore, a diet is of too wide a ratio by reason of its containing a large proportion of maize, it would not be wise to attempt to "narrow" the ratio by the help of bran; one of the pulse grains would obviously be more suitable for the purpose.

To take a concrete example of the substitution of foods: Oats, whilst being a very suitable and safe-feeding horse-corn, are admittedly a very expensive grain. When compared with other foods by the prices per boll, oats appear in a favourable light, but when the weights of the different grains are considered (and this of course is the crucial test) they will be seen to be the dearest corn in the market. Taking wholesale prices, the following comparative values may upon an average be considered as approximately correct, and from them it appears that oats and beans cost about the same price per ton, whilst maize is infinitely cheaper than either.

TABLE V.

Food.	Weight per Boll. Pounds.	Price per Boll. s. d.	Price per Ton. £ s. d.
Oats	84	4 9	6 7 0
Beans	126	7 3	6 9 0
Maize	120	4 9	4 9 0

When the comparative feeding values of these foods are considered, the difference becomes even more marked (Table I.). In estimating the comparative values of foods, agricultural chemists sometimes adopt what is called the unitary system of calculation, which, though not accurate in detail, is useful as affording a rough indication. Every unit per cent. of albuminoids, fats, and carbohydrates in the foods is valued at 3s., 2s., and 1s. respectively. Adopting these figures, we obtain the comparative values of these three foods, as shown in Table VI.

TABLE VI.

				£ s. d.
Oats—	Albuminoids	8·5 per cent. at	3s.,	1 5 6
	Fats	4·0 ,,	2s.,	0 8 0
	Carbohydrates	45·0 ,,	1s.,	2 5 0
				£3 18 6
				£ s. d.
Beans—	Albuminoids	19·6 ,,	3s.,	2 18 9
	Fats	0·7 ,,	2s.,	0 1 5
	Carbohydrates	49·3 ,,	1s.,	2 9 3
				£5 9 5

			£	s.	d.
Maize—Albuminoids	7·3 per cent. at	3s.,	1	1	11
Fats	3·7 ,,	2s.,	0	7	5
Carbohydrates	68·0 ,,	1s.,	3	8	0
			£4	17	4

Pursuing this method, it would seem that the comparative values of beans and oats are as £5 9s. is to £3 18s., so that with beans at £6 9s. per ton, the equivalent value for oats would be about £4 12s. per ton. Again, the comparative values of maize and oats are as £4 17s. is to £3 18s., so that with maize at £4 9s. per ton, the equivalent value for oats would be about £3 12s. per ton. It must of course be understood that such an arbitrary system of valuation is not applicable where the market-price of any one given food is required, but is fairly serviceable in comparing the values of two or more foods one with another. The method, moreover, takes account of no other properties of the foods than their chemical composition, so that such important considerations as palatability, effect on the bowels, age, and condition of the foods are neglected.

Seeing, then, that both beans and maize contain a greater number of food-units than oats, and considering also the prices per ton at which the three foods can be purchased, a saving would be effected by substituting a mixture of maize and beans either wholly or partly for oats. In making such an alteration in a diet, two points must be brought into line: (1) The correct proportion in which the two foods must be blended to furnish approximately the same albuminoid ratio as that of oats; and (2) the quantity of the mixture that would be required to supply an equivalent of the nutrient matter contained in the oats. With a little calculation it will be found that a mixture of maize and beans in the proportion of $2\frac{3}{4}$ of the former to 1 of the latter will provide approximately the same albuminoid ratio as oats. Thus:—

		Albuminoids.	Carbohydrates.	Fats.
100 pounds of beans contain		19·6	49·3	0·70
275 ,, maize ,,		20·1	187·0	10·17
375 ,, mixture ,,		39·7	236·3	10·87

This mixture contains 39·7 flesh-forming units and [236·3 + (10·87 × 2·3) =] 261·3 heat-forming units. This is practically 40

of albuminoids to 260 of heat-formers, namely, a ratio of 1 to 6·5, which is sufficiently near to that of oats for all practical purposes. Next, what quantity of oats is necessary to supply 40 of albuminoids and 260 of heat-formers, which are the nutrients contained in 375 pounds of the mixture? Using the ordinary method of proportion, it will be found that about 475 pounds of oats would be necessary, containing about 40 pounds of albuminoids, 213¾ pounds of carbohydrates, and 19 pounds of fats. The heat-forming units are [213¾ + (19 × 2·3) =] 257½; and the albuminoid ratio is as (1 : 257½ ÷ 40 =) 1 to 6·4. Thus 475 pounds of oats could be replaced by 375 pounds of the mixture, the latter being blended in the proportion of about 2¾ parts of maize to 1 part of beans. The numbers 475 and 375 are in the proportion of 19 to 15, therefore the matter may be practically interpreted as follows:—19 cwts. of oats are the equivalent of 15 cwts. of a mixture composed of 11 cwts. of maize and 4 cwts of beans. Roughly, about 0·8 pound of the mixture is seen to be equivalent to 1 pound of oats.

The following is an example of a ration adopted by a tramway company, and arranged more or less on this system:—14 pounds of hay, 12 pounds of maize, 4 pounds of beans, and 1 pound of bran. Here, the maize and beans are in the proportion of 3 to 1, and the whole diet gives an albuminoid ratio of about 1 to 6·9.

A further example may be given, which is a ration successfully employed in a stud of colliery-horses, and here the different foods are apportioned by weight in the diet somewhat as follows:—29 per cent. of hay, 12 per cent. of peas, 4 per cent. of beans, and 55 per cent. of maize. In this case, the maize and pulse grain are present in the proportion of about 3½ to 1, and as a consequence the ratio of the diet is widened to 1 to 7·3.

It would seem from the above examples that a mixture of maize and pulse in the proportion of 3 to 1 gives satisfactory results in practice, but to what extent such alterations and modifications in diet as above suggested could be established in colliery-rations was to have formed the subject of practical experiment. These experiments were cut short in their initial stages, owing to circumstances over which the writer had no control, and for the present, at any rate, they have been abandoned.

Mineral Salts.

In the earlier portion of this paper reference was made to this subject. Table VII. contains the quantities of the most important mineral constituents in 1,000 parts of ordinary horse-foods. Of

Table VII.

Food.	Phosphoric Acid.	Lime.	Potash.	Soda.
Oats.....	5·5	1·0	4·2	1·0
Maize....	5·5	0·3	3·3	0·2
Beans	11·6	1·5	12·0	0·4
Peas.....	8·8	1·2	9·8	0·9
Bran.....	28·8	2·6	13·3	0·3

the four mineral salts mentioned here, phosphoric acid and lime are quantitatively by far the most important to the animal, as they constitute together about 80 per cent. of the total mineral matter of the body. It may at once be said that only under quite exceptional circumstances is a diet deficient in mineral matter, and the deficiency is liable to occur only in the cases of young rapidly-growing animals and milch cows. It is, however, interesting to notice that in comparison with oats, maize is deficient in lime and soda; while beans and peas are for the most part strong where the maize is weak, containing four to five times as much lime as maize, and two to four times as much soda. So that in this, as in almost every other respect, the pulse-grains supply the deficiencies of maize. The very small quantity of lime present in maize (only about 0·03 per cent.) largely accounts for its unsuitability as a food for young growing animals, and at the Rothamsted research-station it was found that pigs fed for experimental purposes exclusively on maize benefited greatly in general health by the addition of superphosphate of lime to their diet.

Common salt is to some extent an exceptional mineral, as almost all animals, especially young ones and hard-worked horses, benefit by the addition of a small quantity to their food. It is credited with the property of assisting digestion and circulation, and it also acts as a stimulant to the vital functions of the body.

In concluding this paper, the writer would like to acknowledge his indebtedness to the many colliery and stable-managers who have so willingly assisted by placing their records and results of experience at his disposal.

The PRESIDENT (Mr. H. C. Peake), in moving a vote of thanks to Mr. F. O. Solomon for his valuable paper, said that the writer's views were not altogether in accordance with those of Mr. C. Hunting,* as he gave rather more poor food, such as hay and straw, than Mr. Hunting recommended. He (Mr. H. C. Peake) had fed his stud in accordance with Mr. Hunting's suggestions, with economical and successful results.

The motion was cordially approved.

Mr. G. A. DENNY's "Observations on Sampling, Computation of Assay-averages, and Relation of Assay-value to Recovery-value as applied to Banket-mining in the Transvaal" was read as follows:—

* *Trans. N.E. Inst. M.E.*, 1882, vol. xxxii., page 61.

OBSERVATIONS ON SAMPLING, COMPUTATION OF ASSAY-AVERAGES, AND RELATION OF ASSAY-VALUE TO RECOVERY-VALUE AS APPLIED TO BANKET-MINING IN THE TRANSVAAL.

By G. A. DENNY.

Introduction.

The importance which the function of sampling bears to the economy of mining is almost pre-eminent. Not only is this statement true regarding the first valuation of metalliferous deposits, in which it is made the arbiter of truth respecting the market-worth of the said deposits, but it is equally true in its relation to the current working of mines in their industrial aspect.

Without prejudice to the foregoing statements, it may be said, however, that certain natural conditions modify or amplify the great importance which is thus claimed for systematic sampling. It is modified, for instance, in cases where ore-shoots occur in disconnected pockets or chimneys, as frequently happens in silver-deposits; it is amplified in cases where in the strike-direction of a given reef, payable ore-shoots of regular tenour and direction occur, separated from one another by unpayable shoots equally regular in direction and value.

As it is improbable that any differences of opinion exist regarding the importance of this branch of mining-work, it is unnecessary to adduce data in support of statements which are practically self-evident. The writer may therefore confine himself to the subject of his paper, namely, sampling and its attendant functions in relation to mining economy.

It is only within recent years that the importance of the operation of systematic sampling has been recognized. Doubtless there has always been, even in mines where the most "rule-of-thumb" methods obtain, some attempt at arriving at the value of the ore by sampling, but it is quite certain that the work was performed

most perfunctorily, and without any system or record. Also the fashion was to leave this work to a man whose bias was usually in the direction of securing the most favourable results, and hence an altogether untrustworthy value was obtained. To this cause may be attributed many of the lamentable failures made by mines to return yields in any manner proportionate to those anticipated.

It is obvious that sampling methods are directly valuable as to the amount of ore which is developed in a given mine. The most careful sampling of an open surface-cutting, 25 feet in length, gives no criterion of value beyond that limit, and as in practice such a limit is economically impracticable, the data so acquired can strictly be applied only to the spot in question, although on a satisfactory showing these would give an impetus to the extension of the prospecting work, until ultimately sufficient ore had been disclosed upon which to base definite figures.

In modern mining practice, it is, however, recognized that a well-developed mine, in the sense not only of having properly planned workings, but also in the sense of having a large reserve of ore ahead of the mill requirement, is a *sine qua non* of successful mining operations.

On the Witwatersrand, the importance of this factor has been fully realized, and it is not uncommon to find mines with three to five and even seven years' crushing in sight. As the writer is at present somewhat intimately connected with the mining industry of the Witwatersrand, he proposes to cite the methods of sampling and attendant functions used in the mines with which he is connected, as illustrative of the subject-matter of this paper.

The banket-reefs of the Witwatersrand have become famous for the average tenour of the ore which they yield. It is a matter of common opinion, at least among the unscientific, that there is practically no variation in the value of rock within the limits of a mine-holding. It is known that fluctuations do occur in the value of the reefs, from the incontrovertible evidence afforded by the yield of various mines, but it is also imagined that these fluctuations are in the gross, and occur rather as characteristic of districts than of limited zones. The writer's experience in quartz-mining in various parts of the world led him to the inevitable conclusion that gold occurs in certain well-defined streaks or shoots in reefs, the " pay-streaks " representing that portion of the reef

which is most highly charged with gold. These streaks or shoots usually maintain well-defined characteristics, both as to value and direction.

When first studying the subject of the genesis of the Rand banket-reefs, the conviction was borne in upon the writer's mind, that similar phenomena could be traced in the gold-occurrences, that is to say, in taking a given length of perhaps 2,000 feet, a study of the values would disclose a zoned aspect, each zone representing a value-variation. Further investigation indicated that the width of these zones could be projected from level to level in a mine with great certainty, proving that they showed features comparable in all respects with the shoots or streaks recognized in quartz-mining.

Again, in connexion with banket-reefs, it is popularly supposed that they present no practical variation in width. This impression is absolutely erroneous. It is not infrequently found that a reef which may be at a given point 6 feet wide, will within a distance of 500 feet on the strike, have disappeared in stringers, which bear no resemblance to the large body. As a matter of fact, the reefs are lenticular to a high degree, and in this respect again they are comparable to ordinary quartz-veins.

In sampling on the Witwatersrand, we have therefore conditions almost identical with those which would appear in as extensively developed a field of quartz-mines. The pay-shoots may be, and doubtless are, generally separated by a lesser width of poor rock than is characteristic of shoots in quartz, but the general aspect of the case remains the same.

In the Central Witwatersrand, three distinct bodies of reefs are worked, called the Main Reef, Main Reef Leader and South Reef, of which the Main Reef underlies all; the Main Reef Leader is intermediate, and separated by distances varying from a few inches to 50 feet from the Main Reef; and the South Reef overlies all, distant anything from 10 to 100 feet from the Main Reef Leader.

These reefs are formed of a glassy conglomerate of quartz-pebbles, set in a quartzitic cement, which contains a varying percentage of iron-pyrites, and sometimes as accessory minerals, small quantities of zinc-blende, galena, and copper-pyrites, while along with the gold, occurs a minute quantity of platinum and allied metals. The general stratigraphy of the country immedi-

ately connected with the banket-deposits may be summarized as layer upon layer of grits and quartzites, with interbedded and ramifying dykes of diabasic material.

Supposing then, that we have a mine developed and ready for valuation, it remains to describe the various operations involved.

The writer may start by saying that the sampling of the mine —obviously the first operation—is entrusted to men of experience, who take as their equipment a water-squirt (with which to wash down the rock at the point to be sampled), hammer, chisels (both diamond and chisel-pointed), a receptacle in which to catch the samplings, and sacks about 15 inches deep and 9 inches wide wherein to place the completed sample. In South Africa, the sampler is usually assisted by two Kaffirs. The sampler first proceeds to measure equal distances along the level, rise, or other working which he is to sample. The distances taken are either 5 feet or 10 feet intervals; in the case of thin rich leaders, always 5 feet. Having chalked or otherwise marked the intervals, he proceeds to the work of sampling. In cases where the reef is thin, say only from 1 to 3 inches in width, the sample is taken over a width of 6 inches, that width being carefully channelled out to a certain breadth and depth, so that as nearly as possible a true average may be obtained. Samples should be taken of approximately a minimum weight of 5 to 6 pounds, in general the bigger the sample the nearer it is to the true average, and to the ideal—which latter would be the entire mine. In cases where the reef is solid, that is, where it contains no interbedded quartzite (or "waste" as it is colloquially termed) and is less than 18 inches wide, the total width is sampled as one section. If the reef be solid and greater than 18 inches in width, it is sampled in so many sections of 18 inches, each section being separately sacked and recorded. The object of thus dividing the total thickness into sections is to minimize the danger of getting disproportionate quantities of ore in any section of the sampled width; which can easily occur, if the ore varies in character on the hanging- and foot-wall sides. In cases where the reef (Fig. 1, Plate XII.) is divided into bands of ore and quartzite, only the ore is sampled, the bands of waste being measured, and calculated in the total sampled width, in the following manner:—

The various thicknesses of the bands of the reef are measured,

as follows:—A, reef, 6 inches; B, waste, 12 inches; C, reef, 10 inches; D, waste, 30 inches; and E, reef, 2 inches, with a total width of 60 inches. Assume that the reef assays as follows:—A, 15 dwts. per ton; B, 20 dwts. per ton; and C, 60 dwts. per ton. The average value of the total width sampled would be as shown in Table I. The average result shows that the 60 inches assays (410 ÷ 60 =) 6·83 dwts. per ton. In a later portion of this paper, the writer will give the rationale of this system of calculating assay-averages.

TABLE I.

Band.	Width of Band. Inches.	Nature of Band.	Assay-value per Ton. Dwts.	Assay-inches
A	6	Reef	15	90
B	12	Waste	Nil	0
C	10	Reef	20	200
D	30	Waste	Nil	0
E	2	Reef	60	120
Totals	60		6·83	410

The importance of accurately measuring the sampled width cannot be over-estimated, as a simple illustration will show. Assume that the sampler is working along a rich drive on a clean reef, which he returns as 4 inches in width, when the actual measurement is 3 inches. Then, the measured width, 4 inches at a value of, say, 100 dwts. per ton, equals 400 assay-inches, and the average result on a 36 inches stope is 11·1 dwts. per ton. The actual width of 3 inches at 100 dwts. per ton, or 300 assay-inches, is worth 8·3 dwts. per ton on a stoping width of 36 inches. The recovery-value from 11·1 dwts. per ton, mine-assay, and no sorting, is 26·6 shillings per ton, and for 8·3 dwts. per ton is 19·9 shillings per ton, and the difference in ultimate recovery made by the mistake in measurement is 6·7 shillings per ton.

Of equal importance in the calculation of the resulting assay-values is the consideration of the intervals at which samples are taken in the total length of working represented. If taken promiscuously, although over a great length of drive, the results obtained might be either very much above or below the true average, that is assuming the total distance sampled were used in the calculation of averages. Let us, for instance, take a drive 150 feet long which has been sampled irregularly, and for the purposes

of the illustration let the reef be, in each instance, 6 inches wide. Let samples now be taken at the following intervals, which give the assay-results shown in Table II., of (7,080 ÷ 66 =) 107·2 dwts. per ton.

TABLE II.—FIRST METHOD.

No. of Sample.	Distance from Starting-point. Feet.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.
1	10	6	50	300
2	25	6	80	480
3	30	6	150	900
4	35	6	125	750
5	50	6	15	90
6	80	6	20	120
7	120	6	40	240
8	125	6	300	1,800
9	128	6	250	1,500
10	135	6	140	840
11	150	6	10	60
Totals	150	66	107·2	7,080

Now, taking this average out properly, and, in the absence of tonnage developed, using feet sampled as our fundamental factor, we obtain for each interval its proper value, as shown in Table III., of (8,880 ÷ 150 =) 59·2 dwts. per ton.

TABLE III.—SECOND METHOD.

No. of Sample.	Length of Reef. Feet.	Thickness of Reef. Inches	Assay-value per Ton. Dwts.	Assay-feet.
1	10	6	50	500
2	15	6	80	1,200
3	5	6	150	750
4	5	6	125	625
5	15	6	15	225
6	30	6	20	600
7	40	6	40	1,600
8	5	6	300	1,500
9	3	6	250	750
10	7	6	140	980
11	15	6	10	150
Totals	150	66	59·2	8,880

The comparative results, 6 inches average-assays, are as follow:—First method, 107·2 dwts., and second method, 59·2 dwts. per ton. This great difference is introduced obviously in the first case by assuming in the calculation that the samples are taken at equal distances, thus making every block bear an equal proportion

in the total length, whereas in reality they are taken very irregularly.

Assume again that the same length of drive were sampled at 10 feet intervals with the assay-result as shown, then whether the first or second method of calculation last employed be used the result is the same, as shown by Tables IV. and V. The average value, by the first method, is (7,020 ÷ 90 =) 78 dwts., and by the second method, it is also (11,700 ÷ 150 =) 78 dwts.

TABLE IV.—FIRST METHOD.

No. of Sample.	Distance from Starting-point. Feet.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.
1	10	6	50	300
2	20	6	80	480
3	30	6	150	900
4	40	6	60	360
5	50	6	50	300
6	60	6	30	180
7	70	6	40	240
8	80	6	20	120
9	90	6	50	300
10	100	6	40	240
11	110	6	50	300
12	120	6	40	240
13	130	6	300	1,800
14	140	6	200	1,200
15	150	6	10	60
Totals	150	90	78	7,020

TABLE V. SECOND METHOD.

No. of Sample.	Length of Reef. Feet.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-feet.
1	10	6	50	500
2	10	6	80	800
3	10	6	150	1,500
4	10	6	60	600
5	10	6	50	500
6	10	6	30	300
7	10	6	40	400
8	10	6	20	200
9	10	6	50	500
10	10	6	40	400
11	10	6	50	500
12	10	6	40	400
13	10	6	300	3,000
14	10	6	200	2,000
15	10	6	10	100
Totals	150	90	78	11,700

Again, if the samples be equidistant, and the reef of the same width throughout, the average is obtained without further calculation by dividing the sum of the assay-dwts. by the number of samples taken; but if, on the other hand, the samples be equidistant and the widths of reef variable, the application of this method gives an entirely incorrect result of (930 ÷ 37 =) 25·1 dwts. per ton, as shown, say on a length of 50 feet, in Table VI.

TABLE VI.

No. of Sample.	Distance from Starting-point. Feet.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.
1	10	20	10	200
2	20	4	30	120
3	30	6	40	240
4	40	5	50	250
5	50	2	60	120
Totals	50	37	25·1	930

By dividing the total dwts. by the number of samples, we obtain (190 ÷ 5 =) 38 dwts. as the average on (37 ÷ 5 =) 7·4 inches, but by correctly averaging the result we get 25·1 dwts. as the average value on 7·4 inches, a difference of 12·9 dwts. on the lower side, by using the correct means of calculation.

RATIONALE OF COMPUTING METHODS.

For the purposes of this paper, the writer will assume that a 5 feet sampling has been accurately conducted in a well opened-out mine, and that an assay-plan showing the point at which each sample has been taken has been prepared, reflecting the thickness of the reef sampled and the assay-value of the same.

The annexed diagram (Fig. 2, Plate XII.) shows in longitudinal section a reef in a level which has been sampled at the points A, B, C, D, E and F, and the thickness of the reef sampled and the assay-values at each point are recorded in Table VII. It will be noticed that the reef is everywhere less than 30 inches thick.

TABLE VII.

Designation of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.
A	18	32
B	20	25
C	12	48
D	15	10
E	19	11
F	14	17

The old method of finding the average value of this reef is shown in Table VIII.

TABLE VIII.

Designation of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.
A	18	32
B	20	25
C	12	48
D	15	10
E	19	11
F	14	17
Totals	98	143
Averages	16·34	23·83

According to the statement contained in Table VIII., the value would be given as (143 ÷ 6 =) 23·83 dwts. over an average thickness of (98 ÷ 6 =) 16·34 inches. In the days when this method was used, it was not customary to calculate upon the width of the stopes to be carried, and whether the stopes were 3 or 6 feet, the product was expected to yield ounce rock. Needless to say the results were disappointing.

By the method of to-day, given the same case, the computation would be one of the two recorded in Tables IX. and X. In Table IX., the average thickness is (98 ÷ 6 =) 16·34 inches, and the value over 36 inches is (62·3 ÷ 6 =) 10·4 dwts. In Table X., the average thickness is (98 ÷ 6 =) 16·34 inches, the assay-value of reef is (2,249 ÷ 98 =) 22·94 dwts., and the assay-value over 36 inches will be (16·34 × 22·94 ÷ 36 =) 10·4 dwts. per ton.

TABLE IX.

No. of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.	Average Value over 36 Inches. Dwts.
1	18	32	576	16·0
2	20	25	500	13·8
3	12	48	576	16·0
4	15	10	150	4·1
5	19	11	209	5·8
6	14	17	238	6·6
Totals	98	...	2,249	62·3
Averages	16·34	...		10·4

The difference between these two methods is that, in the first case each sample individually is worked out to a basis of 36 inches,

while in the second the whole are grouped together and reduced in one calculation. For reasons which will appear later, the writer prefers to check one by the other in each calculation.

TABLE X.

No. of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.
1 ...	18 ...	32 ...	576
2 ...	20 ...	25 ...	500
3 ...	12 ...	48 ...	576
4 ...	15 ...	10 ...	150
5 ...	19 ...	11 ...	209
6 ...	14 ...	17 ...	238
Totals ..	98	...	2,249
Averages	16·34	...	22·94

To indicate still more clearly the inaccuracy of the old method, take the case calculated in Table XI. The assay-value is (14 × 37 ÷ 36 =) 14·4 dwts. over 36 inches.

TABLE XI.

No. of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.
1 ...	2 ...	100
2 ...	30 ...	5
3 ...	10 ...	6
Totals ...	42	111
Averages ...	14	37

By the correct method, the results are as shown in Table XII.

TABLE XII.

No. of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.	Average Value over 36 Inches. Dwts.
1 ...	2 ...	100 ...	200 ...	5·5
2 ...	30 ...	5 ...	150 ...	4·2
3 ...	10 ...	6 ...	60 ...	1·6
Totals	42	...	410	11·3
Averages	14	...	...	3·8

The average value on 14 inches is (410 ÷ 42 =) 9·76 dwts., and on 36 inches it is (9·76 × 14 ÷ 36 =) 3·8 dwts. per ton. The difference of 10·6 dwts. obtained by the use of these methods represents the error by the old method.

The results obtained by employing the old method indicate a payable ore, while the actual value as shown by the second calculation is unprofitable.

If stoping could be carried to the exact thickness of the reef at every point, and the reef-matter fed into the mill as free from extraneous rock as it stands in the mine, then a very close sampling throughout the mine, computed on the average thickness in assay-inches, should be theoretically correct, but in practice it is impossible to stope below a certain thickness, and consequently at the points where the reef is thin, a considerable amount of the country-rock has to be included with it, thereby reducing its value, as shown by the above statements.

Take, for instance, in Fig. 3 (Plate XII.) the sample at A, 2 inches thick, assaying 100 dwts. per ton. It is impossible to stope 2 inches, and as in the immediate vicinity the reef is 30 inches thick, the stope would probably be carried to that thickness. The 2 inches thickness of reef assaying 100 dwts. per ton is now diluted by the additional 28 inches of waste carrying nothing, and the average over 30 inches is (200 ÷ 30 =) 6·67 dwts. per ton, as shown in Table XIII.

TABLE XIII.

No. of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches
1 ...	2 ...	100 ...	200
2 ...	28 ...	0 ...	0
Totals ...	30		200
Average		...	6·67

At this stage, the following explanatory notes will make the present method of computation clear:—

(1) The assay-inch is the product of 1 inch in thickness multiplied by the assay-value over the whole thickness sampled.

(2) At any given point of a reef, the total number of assay-inches is represented by the product of the number of inches sampled, multiplied by the assay-value over that thickness.

(3) The total number of assay-inches at any given point of a reef, divided by the thickness sampled, will yield the average value over that thickness.

(4) The total number of assay-inches at any given point of a

reef, divided by a thickness greater than that sampled, will yield the average value over the greater thickness.

(5) The total number of assay-inches at any given point of a reef, divided by a thickness less than that sampled, will yield a misleading result.

TABLE XIV.

Designation of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.	Average Value over 30 inches. Dwts.
A	40	9	360	9
B	41	14	574	14
C	38	11	418	11
D	36	17	612	17
E	32	8	256	8
F	39	12	468	12
Totals	226	71	2,688	71
Averages	37·67	...	11·8	11·8

TABLE XV.

Designation of Sample.	Thickness of Reef. Inches.	Assumed Thickness of Reef. Inches.	Assay value per Ton. Dwts.	Assay-inches.	Average Value over 30 Inches. Dwts.
A	40	30	9	270	9
B	41	30	14	420	14
C	38	30	11	330	11
D	36	30	17	510	17
E	32	30	8	240	8
F	39	30	12	360	12
Totals	226	180	71	2,130	71
Averages	37·67	30	...	11·8	11·8

The diagram, Fig. 4 (Plate XII.), shows a reef averaging over 30 inches in thickness, and in which no sample is taken over less than that thickness. In such a case, it is customary to take the lowest width and work out the average on that basis. If, however, a standard of, say, 30 inches has been adopted for the width in a mine, the values as upon the greater width or the 30 inches remain the same (11·8 dwts.), as shown in Tables XIV. and XV. In Table XIV., the average thickness of reef is (226 ÷ 6 =) 37·67 inches, the average value of the reef (2,688 ÷ 226 =) is 11·8 dwts., and the average value over 30 inches is also (71 ÷ 6 =) 11·8 dwts. In Table XV., the average thickness of reef is (226 ÷ 6 =) 37·67 inches, and the average value over 30 inches is (2,130 ÷ 180 =) 11·8 dwts. From these figures (Tables XIV. and XV.), it

is obvious that where all the samples are taken over a thickness of more than 30 inches the value may be calculated on 30 inches without affecting the result.

On the other hand, one may meet with the features represented in Fig. 5 (Plate XII.). It will be observed that in this section there are some samples taken over a greater, and some over a lesser thickness than 30 inches.

By Tables XIV. and XV., it was shown that where all the samples averaged over 30 inches in thickness, the results came out the same, whether the greater thickness or only 30 inches were employed in working out the calculation. In a case such as the one under notice, however, in which there are several samples measuring less than 30 inches, a different procedure must be adopted in order to obtain accurate results. To show this clearly, take the three calculations, recorded in Tables XVI., XVII. and XVIII.

TABLE XVI.

Designation of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.
A	40	60	2,400
B	33	28	924
C	25	32	800
D	20	24	480
E	17	30	510
F	38	12	456
Totals	173		5,570
Averages	28·83		32·19

By Table XVI., the average thickness of reef is (173 ÷ 6 =) 28·83 inches, and the average value is (5,570 ÷ 173 =) 32·19 dwts., the assay-value over 30 inches is (28·83 × 32·19 ÷ 30 =) 30·93 dwts., and 32·19 dwts. over the average thickness of reef of 28·83 inches.

TABLE XVII.

Designation of Sample.	Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.	Average Value over 30 Inches. Dwts.
A	40	60	2,400	60·00
B	33	28	924	28·00
C	25	32	800	26·67
D	20	24	480	16·00
E	17	30	510	17·00
F	38	12	456	12·00
Totals	173	...	5,570	159·67
Averages	28·83	...	...	26·61

By Table XVII., the average thickness of reef is (173 ÷ 6 =) 28·83 inches, and the average value over 30 inches is (159·67 ÷ 6 =) 26·61 dwts. per ton.

TABLE XVIII.

Designation of Sample.	Thickness of Reef. Inches.	Assumed Thickness of Reef. Inches.	Assay-value per Ton. Dwts.	Assay-inches.
A	40	30	60	1,800
B	33	30	28	840
C	25	25	32	800
D	20	20	24	480
E	17	17	30	510
F	38	30	12	360
Totals	173	152	...	4,790
Averages	28·83	25·34	...	31·51

By Table XVIII., the average assumed thickness of reef is (152 ÷ 6 =) 25·34 inches, the average value is (4,790 ÷ 152 =) 31·51 dwts., the value over an average thickness of 30 inches is (25·34 × 31·51 ÷ 30 =) 26·61 dwts. per ton, and the average thickness of reef is (173 ÷ 6 =) 28·83 inches.

In the calculation shown in Table XVI., the full thickness sampled is in each case multiplied by the assay-value over that thickness, and the sum of the resultant assay-inches is divided by the total sum of the thicknesses. The result shows an average of 32·19 dwts. over an average thickness of 28·83 inches, equal to 30·93 dwts. over 30 inches.

In the calculation shown in Table XVII., the average of each individual sample is worked out over 30 inches and the total divided by the number of samples, showing an average value of 26·61 dwts. over 30 inches.

In the calculation shown in Table XVIII., the thickness of reef is assumed to be only 30 inches in such cases where it is greater than that, while samples less than that thickness are reduced to a basis of 30 inches. The total inches in thickness are then divided into the total assay-inches, and the result is the same as that shown in Table XVII.

Obviously, therefore, in view of the difference of the results obtained, there is something wrong in the method adopted in Table XVI., or in Tables XVII. and XVIII. In brief, the calculation

shown in Table XVI. is wrong for the following reason. The first assay in the list is:—

Designation of Sample.	Thickness of Reef.	Assay-value per Ton.	Assay-inches.
	Inches.	Dwts.	
A ...	40 ...	60 ...	2,400

These 2,400 assay-inches are included in the sum of the assay-inches, and are subsequently reduced to a basis of 30 inches. It will be remembered that in No. 5 of the explanatory notes before given,* the following axiom was laid down:—The total number of assay-inches at any given point of a reef, divided by a thickness less than that sampled, will give a misleading result. The method adopted in Table XVI. is as follows:—40 inches × 60 dwts. ÷ 30 inches = 80 dwts. The effect of this calculation is to concentrate the number of assay-inches contained in 40 inches assaying 60 dwts. into 30 inches assaying 80 dwts. To show how absurd this is, assume that the standard width adopted was 6 inches. Then the 2,400 assay-inches divided by 6 inches equal 400 dwts. assay-value over 6 inches. It is clear that, if we have a reef 6 feet thick, averaging 1 ounce over that thickness, and out of which we take only 2½ feet, the remaining 3½ feet will still average 1 ounce, whereas by the calculation adopted in Table XVI., the whole of the value would be concentrated into the 2½ feet thus increased to a value of 2 oz. 8 dwts., which is of course absurd.

For the purposes of reef-assay valuation, therefore, the easiest rule to follow is to establish a thickness as near to the average of the reef as possible, and to reduce all values over lesser thicknesses to that basis, allowing all averages over greater thicknesses than the standard established to rank as if taken on the exact standard. In the case of very narrow reefs it is advisable to use the lowest average stoping-width as a standard.

Of the preceding calculations, that shown in Table XVII. is to be preferred, being simple and at the same time more detailed in the information afforded.

Assay-records and Plans.

The records of the sampling as it proceeds are duly entered in a book kept for the purpose, and ruled in columns somewhat as shown in Table XIX.

* *Trans. Inst. M.E.*, vol. xix., page 305.

TABLE XIX.—NAME OF MINE.

Date.	No. of Sample.	Working-place.	Reef.	Width of Reef.	Width Sampled.	Assay-value.	Value over 48 Inches.
				Inches.	Inches.	Dwts.	Dwts.
Sept. 1	1	No. 1 Shaft ... ... Fifth Level East Drive	South Reef	12 (reef) 10 (waste)	15	20·0	
,,	2	,,	,,	18 (reef)	20	10·0	10·4*

* More reef in hanging-wall.

In the form used, the column, "Value over 48 inches," is left blank in respect of the width, to allow for the difference of stope-width intended.

In addition to the record of samples entered in the form just described, an assay-plan is also kept. This plan is made and kept by the mine-surveyor. It should be drawn on the plane of the reef, at a scale of not less than 1 to 500, and should be a complete copy of the mine working-plan. It is a very usual custom to have a combined stope- and assay-plan, which is brought up to date month by month as the stopes advance, and shows all assays taken in workings of any kind whatsoever. In the case of working more than one reef, as is general in the Central Witwatersrand, a separate plan must be kept for each reef.

Many systems are in vogue for marking the assay-results on the plan, but of these only two are commendable. The first is to show at each point sampled the full details of the sample as indicated in Fig. 6 (Plate XII.), the widths being shown in black (left-hand of vertical line) and the assay-values in red (right-hand): the top line of figures always referring to the hanging-wall side of the reef.

The second system is to show at each point the calculated value on the width which it is proposed to stope. If the sample taken is only 36 inches wide at one point and 60 inches wide at another, and it is proposed to stope 48 inches, the value in the first instance must be reduced to that over the greater width of 48 inches, and in the second would be shown on the total width. For the purpose of illustration, let the samples be taken to assay 20 dwts. over 36 inches, and 12 dwts. over 60 inches, they would appear on the plan as indicated in Fig. 7 (Plate XII.).

The writer prefers the latter system, which gives at a glance the values of the estimated stoping-width.

It is not unusual to find on the Rand, to-day, assay-plans show-

ing the result of sampling as indicated in Figs. 8 and 9 (Plate XII.). The first case (Fig. 8) is perfectly correct, but it is inconvenient; the second case (Fig. 9) is quite misleading, inasmuch as the intervening thickness of waste (which has to be mined) is not shown, and a result calculated out on the figures as given would far exceed the correct average.

Computation of General Averages.

The development of Witwatersrand mines is carried out on one general plan, only modified by circumstances of variations in dip and contingencies of ore-winning. As a general rule, it may be said that levels are placed at distances of 120 to 150 feet apart, measured on the reef-inclination, and the winze-connexions are made from 300 to 500 feet apart, usually nearer the former than the latter figure. The sampling is carried on systematically at the stipulated distance-interval, completely round the blocks of developed ground.

The final average values of the developed ground are based either on the tonnage contained or on the distance sampled, or both. In the first instance, the total number of feet sampled is accurately averaged, as shown in the former illustration (Fig. 7, Plate XII.), then against the total feet sampled round various developed blocks, is put the average assay-value, arrived at by the methods already described.

Of the two methods, the basis of tonnage contained is undoubtedly the better, seeing that this gives an average of the total tons which it is estimated will be mined. The calculation is illustrated in Fig. 10 (Plate XII.) and Table XX. The average value is (415,000 ÷ 29,000 =) 14·3 dwts. per ton. Similarly if the "distance sampled" be taken as the basis for calculation, the sum of the distances, divided into the sum of the products of the distances by the values, will show the average value.

Table XX.—Average Value of the Developed Tonnage.

Designation of Block.	Contents of Block. Tons.	Average Value per Ton. Dwts.	
A ...	10,000 ...	12 ...	120,000
B ...	14,000 ...	15 ...	210,000
C ...	5,000 ...	17 ...	85,000
Totals ...	29,000 ...	14·3 ...	415,000

Relation of Assay-value to Recovery-value.

The most careful and systematic methods of sampling and averaging are yet dependent upon certain other functions which cannot be accurately gauged. If, for instance, the average of a given block of ground is reckoned out as upon a 4 feet stoping-width, and the value upon that width averages 14 dwts. per ton, and if, in the course of actual mining, the stope, owing to uncontrollable causes, cannot be kept narrower than 5 feet, the value of the ore mined drops from 14 dwts. per ton to 11·2 dwts. It may be accepted as a general axiom that variation in this respect is directly proportional to the reef-width, the greatest variation being attained in the narrowest reefs. As a practical factor, the writer allows for a variation of 20 per cent. in the estimated assay-value of the ore on reefs below 6 feet in width and its actual value as delivered at the shaft-mouth; on reefs between 6 and 9 feet, a variation of 15 per cent.; and on reefs above 9 feet a variation of 10 per cent., the variation in each case being on the lower side. That is to say: Assuming that on a carefully sampled block of ground an average of 15 dwts. on 48 inches width was returned, the actual value of the ore as delivered at the surface would be estimated at 12 dwts.

Having delivered the ore on the surface, it may be sent direct to the mill without sorting, or it may be subjected to a sorting operation. This latter introduces a new factor into the calculation of the relation of assay-value to recovery-value, since by its means a proportion of the barren quartzite or waste-rock is discarded, thus removing a diluent from the reef proper. Naturally, by the most perfect sorting system, only the pieces large enough to pass over the fines-grizzly can be subjected to the operation, and this in some cases does not exceed 60 per cent. of the total rock mined. It is not unusual on the Rand to find mines declaring 40 per cent. of the total rock mined as rejected on the sorting-tables, or in other words, the total ore mined is distributed as follows:—
40 per cent. passes through the grizzly as "fines"; 40 per cent. of the total quantity is rejected on the sorting-floor; and 20 per cent. will represent the sorted ore which passes to the mill. Theoretically, the effect of sorting out 40 per cent. of waste-rock should be as under, taking 100 tons as a basis:—

		Dwts.
100	tons of ore delivered from the mine, assaying	10
40	tons of fines pass through grizzly and go to the mill, assaying	10
60	tons of coarse ore go to the sorting-floor, assaying 10 dwts., and containing...	600
40	tons are rejected on the sorting-floor, assaying 1 dwt., and containing	40
Leaving 20	tons of sorted rock of an average-value of 28 dwts., and containing	560

Of the 100 tons originally taken, there are—

		Dwts.
40	tons of fines at 10 dwts., containing	400
20	tons of sorted rock, at 28 dwts., containing	560; or
60	tons of rock sent to the mill of an average value of 16 dwts., containing	960

From ore, assaying 16 dwts., in the mill-bins, we may reckon on obtaining from the combined mill and cyanide-of-potassium processes, a recovery of 80 per cent. The total recovery-value from 16 dwts. would therefore be 12·8 dwts. Now originally, we started with an ore assaying 10 dwts., as delivered at the surface. Calculating as explained in a former paragraph (that this represents a value 20 per cent. less than the calculated value of the standing ground), the original value of this ore would be 12·5 dwts., which is practically the recovery-value previously shown. Given then the conditions which we have postulated, a developed ore assaying 12·5 dwts., should on a sorting basis of 40 per cent., theoretically yield its full value in recovery. In practice, however, in these circumstances the writer would not use a greater factor than 80 per cent. of the assay-value to represent the probable recovery.

There are, however, but few mines that sort out so high a percentage of the mined rock as that we have just considered. An average of 20 per cent. more nearly describes the conditions of the many. The theoretical effect upon the recovery-value of sorting out 20 per cent. of waste-rock, would then be, on a rock assaying 10 dwts. as delivered at the surface:—

		Dwts.
100	tons of ore delivered from the mine, assaying	10
30	tons of fines pass through grizzly and go to the mill, assaying	10
70	tons of coarse ore go to the sorting-floor, assaying 10 dwts., and containing	700
20	tons are rejected on the sorting-floor, assaying 1 dwt., and containing	20
Leaving 50	tons of sorted rock of an average value of 13·6 dwts., and containing	680

Of the 100 tons originally taken, there are—

	Dwts.
30 tons of fines, at 10 dwts., containing	300
50 tons of sorted rock, at 13·6 dwts., containing ...	680; or
80 tons of rock sent to the mill of an average value of 12·2 dwts., and containing	980

On an 80 per cent. estimated recovery from the mill and cyanide processes, the value would be 9·7 dwts., on an original assay-value of the ore in the mine of 12·5 dwts., and the actual recovery 77 per cent.

On an ore, therefore, assaying 12·5 dwts. in the developed block, from which is rejected 20 per cent. of waste-rock, the theoretical extraction should stand as 77 per cent. of the original assay-value in the mine. As a safety-factor, this figure is better reduced to 70 per cent., which will be found to work out very well in practice.

In a mine, working a 4 feet reef or thereabouts, which does not sort at all, the following figures show the relation of the original assay-value to the recovery-value:—

Ore assaying, in the developed block, say, 15 dwts.; less 20 per cent. allowed for difference in the value of the ore in block and on the surface, or 3 dwts.; then the value of the ore as delivered to the mill-bins will be 12 dwts.; and an 80 per cent. extraction by the mill and cyanide processes will show 9·6 dwts. From an original assay of 15 dwts. we have therefore extracted 9·6 dwts., equal to 64 per cent. In practice, the writer uses for a proposition of this nature a factor of 60 per cent. to represent the recovery-value, or (15 dwts. × 60 per cent. =) 9 dwts.

It must not be forgotten that in introducing sorting on a large scale two important issues arise. Perhaps the more obvious is that (*a*) a given area will produce say 10, 20, or 40 per cent., as the case may be, less tonnage for treatment; and (*b*) the working-and-development costs will be proportionately increased.

For the purpose of illustration let us assume that we are working on a reef, which on a 36 inches stoping-width yields 15,000 tons of ore per claim. Let the reef average 6 inches in width and assay 90 dwts. per ton on that width, or 15 dwts. per ton on the postulated stoping-width. On working such a mine, on a basis

of say 60 stamps and doing no sorting, the result obtained would be somewhat as follows:—Estimated recovery-value, 60 per cent. of assay-value of 15 dwts. or 9 dwts., worth say, 36s.; less estimated costs, including development and redemption of capital under normal conditions, say, 25s.; showing a profit per ton on the working account of 11s.; and a profit per claim of (15,000 tons by 11s. =) £8,250.

Given the same proportion, and figuring on sorting out 30 per cent. of the waste-rock, which forms five-sixths of the total rock mined, the following result would be obtained:—

Original value of ore in mine, 15 dwts.; and value as delivered at surface, 12 dwts.; 30 tons of fines passed through grizzly and sent to mill, assaying 12 dwts.

		Dwts.
70	tons of ore placed on sorting-tables, assaying 12 dwts., and containing	840
30	,, of waste, assaying 1 dwt., and containing	30
Leaving 40	,, of sorted rock, of an average value of 20·2 dwts., and containing	810

Of the 100 tons, there are—

		Dwts.	
30	tons of fines, at 12 dwts, containing	360	
40	,, of sorted rock, at 20·2 dwts., containing...	810	; or
70	,, of rock sent to the mill, of an average value of 16·7 dwts., and containing ...	1,170	

The estimated extraction by the mill and cyanide processes will be (16·7 dwts. by 80 per cent. =) 13·3 dwts.

In figuring on the fines in any given case, attention must be paid to the particular characteristics of the ore. In the case of hard compact ores, the value of the fines from the stopes may be generally placed at 30 per cent. less than that of the larger pieces of ore which are sifted out on the grizzly. In the case of a pyritic banket-ore, averaging 12 dwts. from the stopes, the assay-value of the fines would not be likely to exceed 8 dwts. If this latter figure be adopted in the calculation instead of 12 dwts., the case for sorting would be considerably strengthened, as the value of the sorted product varies inversely as the value of the fines.

The working costs in a sorting system will be directly increased in all the charges under mining, and also for those for mine-

development, as in the first instance 30 per cent. of the rock mined, and in the second case 30 per cent. of the ore regarded as tonnage developed on a 36 inches stope basis is not treated. These items will affect the charges as follows. Assume that, in the first instance, the costs of 25s. per ton are made up as under:—

	s.
Mining	12·0
Milling	3·0
Maintenance	2·0
General charges	1·0
Mine-development, redemption of capital, etc. ...	4·0
Cyaniding	3·0
Total	25·0

When sorting out 30 per cent. of the rock mined, the costs would be somewhat as follows:—

	s.
Mining	17·0
Milling	3·0
Maintenance	2·0
General charges	1·0
Mine-development, redemption of capital, etc. ...	5·7
Cyaniding	3·0
Sorting, say	1·3
Total	33·0

The estimated extraction being 13·3 dwts., or, say, 53s. per ton; less costs, say, 33s. per ton, shows a profit on the working account of 20s. per ton. These figures, in practice, would (in both the case of cost and extraction) work out lower than shown, but the ratio would remain fairly constant; therefore we can figure on, say, 20s. per ton profit.

In the case, therefore, of taking out 15,000 tons per claim, we have seen the profit would amount to £8,250 on that area, and in the case of rejecting 30 per cent. of the ore mined, reducing the material treated to 10,500 tons, the profit per claim at 20s. per ton would be £10,500 or £2,250 per claim more, without taking into account the advantage from a financial aspect of realizing the gross profit to be earned in a much shorter period.

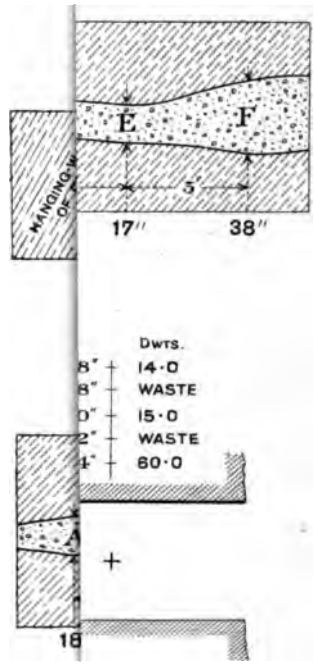
The introduction of a successful slimes-treatment must naturally affect the relation of the recovery-value to the assay-value. The writer may say that, as an all-round figure, 3 dwts. per ton re-

presents the average assay-value of slimes on the Witwatersrand, and, in like manner, 30 per cent. of the ore crushed represents the proportion of slimes produced. If, then, we are running a mill of, say, 50 stamps, the slimes treatment should return results somewhat as follows:—50 stamps crush, say, 7,500 tons of ore per month; the slimes produced equal 30 per cent. of the ore crushed, or, say, 2,250 tons per month; the average value of slimes is, say, 3 dwts. per ton; and with an extraction of, say, 60 per cent. of assay, is 1·8 dwts. per ton.

We have, therefore, recovered by slimes-treatment, another 1·8 dwts. per ton of slimes treated, or 0·5 dwt. per ton of ore milled, or, say, 5 per cent. to add to the actual recovery-value from all sources bringing it from 80 per cent. (the factor used when no slimes are treated) to 85 per cent. when the slimes are under treatment. The losses will be found to figure:—7 per cent. loss in tailings-treatment, 3 per cent. loss in slimes-treatment, and 5 per cent. of unaccounted for loss.

Mr. JOHN M. LIDDELL (Stocksfield-upon-Tyne) wrote that the importance of accurate and systematic sampling of bodies or reefs of gold-ore for the purposes of assay, can hardly be exaggerated. What the scout is to an army in the field, the sampler is to a working mine—the one is no less essential than the other. The business of gold-mining may be usefully divided into two sections:—(1) that of discovering and opening up a gold-bearing body or reef, an undertaking of a speculative character unless governed by evidence from adjoining areas; with that of determining what is the extent and value of the reef or body so discovered: and (2) that of working and recovering gold from a definite ore-body, which has been already proved in extent and value under section (1); and this, if the first section of work has been fully and carefully accomplished, may with fair security be regarded as an industrial operation, which requires a definite capital outlay, will work at an ascertained current cost, and will yield definite gross and nett profits. Indeed in one aspect gold-mining has an advantage over all other industries, in that its product, gold, is sure of a constant and convenient market. It is of course convenient to carry on the two sections of gold-mining simultaneously, but the speculative element decreases as the property becomes developed, and the industry eventually becomes a practical certainty. The

Fig. 8.



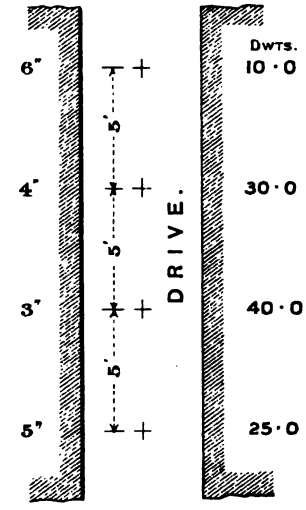


Fig. 9.

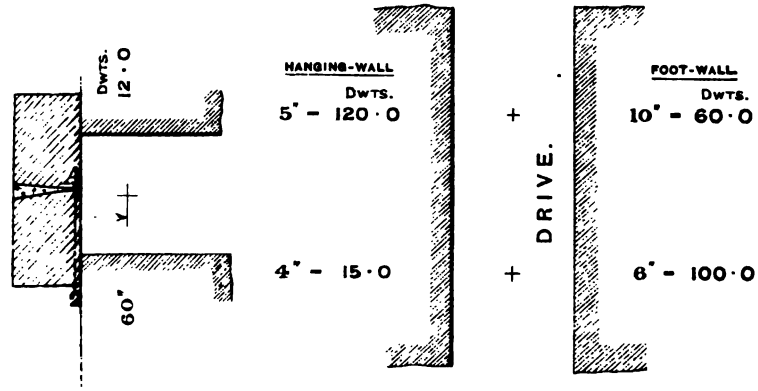
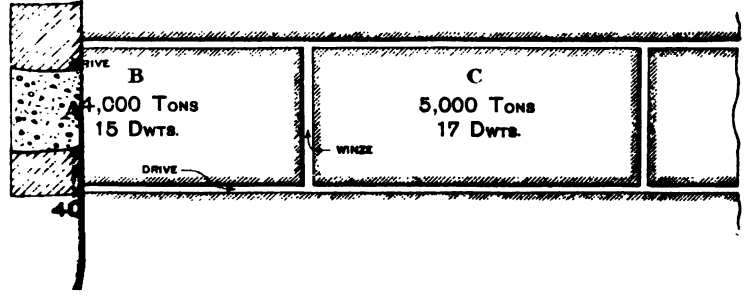


Fig. 10.



necessity of close and regular sampling is indisputable in either section of the work. In working open stopes it is found that gold, always erratic in deposition, may be left in the foot-wall or the hanging-wall, or both, if care be not taken to watch these and also to see that the yield to be expected according to original prospection and evidence from adjoining areas is being obtained. The shoots of gold in the banket vary greatly, influenced by steps in the foot-wall and no doubt by other local causes, and differ from foot to foot in places as to the portions of the banket, and of the foot-wall or of the hanging-wall, in which the banket lies. It is said sometimes that the mill will prove the value of a mine, but its evidence comes too late to be useful, and proves only what has been taken from the mine, ignoring what has been left in it.

The objects of sampling should be considered in two ways:—(1) To discover and follow up the principal shoots of gold, wheresoever they may lead, and after them the poorer shoots, in order to grasp the general lines of the deposit and to secure the richer portions; and (2) after all the circumstances of the reef have been considered in reference both to mining and to milling, and it is decided what shall be regarded as the working reef for mining and milling purposes, the sampling must be directed so as to determine what yield of gold can be depended upon from this working reef in its various areas, and what general average yield of gold per ton may be thus secured to balance against costs of working and recovery in the mill and otherwise. There is always a tendency for samplers to take too much from richer portions of ore in order to give a pleasant aspect to their work, and in hard reefs to sample more from places that have been shattered by blasting or are naturally softer and easier to break, or more convenient of access. The smaller the section of reef from which each distinct sample is taken, the truer will be the evidence obtained, and unless a definite weight is taken from a definite section of reef and the whole mass averaged impartially in figures after assaying and not in ore before assaying, the result is misleading. General averages from a number of sample bags of crushed ore are often useful as checks and for rough testing, but it is an easy matter to go far astray, if much care is not observed in deducing values therefrom. Assay-plans should be kept to show information on the two different principles, namely:—(1) For discovery of gold and the general character of its occurrence; and (2)

for the actual working reef, whereon should be marked the yield at regular intervals, coupled with the thickness of reef to be worked, and for given areas the number of tons to be worked and to yield a total number of ounces of gold in so far as it can be estimated. The second plan can be usefully compared with the results obtained at the shaft and mills showing the ore raised, milled and further treated, with the distribution of the gold to mill-boxes, concentrates, cyanide-vats and tailings. If the assays and assay-plans are carefully maintained, a history of the entire handling of the gold is obtained, and is most valuable and satisfactory to all concerned. The necessity of employing samplers of proved skill and integrity, who shall be free from any undue interest or influence whatsoever, is fully apparent. All reefs, including banket-reefs, contain patches of superlative richness, and it is easy by design or by neglect to produce assay-plans, which show an entirely misleading statement of reef-sections, coupled with assay-values, and which form a picture of past mishandling and most alluring future profits. Good sampling and prospecting is to some extent a gift, and requires much care and local experience to be successful. He considered that Mr. Denny's paper was of the greatest importance and that it was correct in its observations.

Prof. H. Louis (Newcastle-upon-Tyne) said, although he thought highly of Mr. Denny's paper, that he would in the first place like to call attention to what seemed to be an error,* where the writer showed an estimated extraction of 53s. per ton, and a working cost of 33s. per ton, and went on to say that "these figures, in practice, would . . . work out lower than shown, but the ratio would remain fairly constant." He also took exception to the statement that if the method of sorting was employed, a mine could be worked out more rapidly, and a greater profit earned in a much shorter period. He did not see how that opinion could be maintained if the mine were equipped with properly proportioned plant, as the rate of exhaustion depended on the way in which the mine was worked and not on the method of dealing with the mineral on the surface. If Mr. Denny meant that a mine could be worked out more rapidly with than without sampling, for the same size of milling-plant, he (Prof. Louis) entirely agreed with him.

* *Trans. Inst. M.E.*, 1900, vol. xix., page 315.

With regard to the general methods described in the paper, he was not sure that the Rand method of computing the assay-value was altogether correct. That method took a fixed thickness of reef and reduced all less thicknesses to that basis; and on the other hand, if the reef was wider, all averages were reckoned as if taken on the exact standard. He (Prof. Louis) contended that the correct system was to take the assay-value on the actual width stoped, whether wider or narrower than the assumed width. With regard to the general principle of taking samples at intervals of 5 feet and calculating from the measurements and assays so taken, he maintained that this method was wrong, as it confused in one and the same operation two mathematical calculations of very different kinds. The method of taking samples was right—taking averages at uniform lengths and quite haphazard, except as regard the equal distances between them, because sampling is really a problem in probabilities, in which an exact result was only possible when the number of samples was infinite, and only approximations could be obtained in practice; but when they came to a geometrical problem it was not right to measure the reef at uniform distances: they must measure maximum and minimum widths, as they were dealing with forms bounded by curves and not by straight lines, hence the significant points that define the curve must be included in the measurements, whether these points occur at equal distances apart or not. His argument was that a problem in probabilities must be attacked differently from a purely geometrical one. The difference in practice might not be great, but it afforded room for error.

Mr. A. J. Paterson (Queensland) said that in making any estimates upon which the produce of the mine was to be based it would be better to sample each truck as it came out of the mine. He did not think that the produce of a mine could be calculated from the thickness of the reef—a portion of which might at any time vary and contain country-rock—multiplied by the assay-values as described by Mr. Denny. If a sample were taken from each truck as it came out of the mine, a system generally adopted in New Zealand mines, he thought that a very accurate idea of the produce of the mine would be obtained.

A Member suggested that the future produce of a mine could not be accurately based upon the results of the past, as measured

by samples taken haphazard from the trucks as they came out of a mine.

The CHAIRMAN (Mr. H. C. Peake) proposed a vote of thanks to Mr. G. A. Denny for his valuable paper.

Mr. M. WALTON BROWN seconded the motion, which was cordially approved.

Mr. FRANK OWEN's paper on "The Gold-mines of Boulder County, Colorado, U.S.A." was read as follows:—

THE GOLD-MINES OF BOULDER COUNTY, COLORADO, U.S.A.

By FRANK OWEN.

Situation.—The mining districts to which particular reference will be made in this paper are situated within a range of from 10 to 20 miles north and north-west of the town of Boulder. This, the capital town of Boulder county, is a rising and important place of 8,000 inhabitants, and is pleasantly situated in a fertile valley surrounded on all sides by rugged mountains. It is 5,875 feet above sea-level, and distant 29 miles from Denver (5,170 feet), with which city it is connected by the Colorado and Southern railroad. Boulder, besides being the seat of the Colorado State University and the centre for the gold-mining industry of the county, has thriving agricultural and ranching industries, and is gaining considerable repute as a sanatorium for consumptives and other invalids. There are valuable medicinal springs at Springdale. The Colorado and North-Western railroad connects Boulder with the mining villages of Sunset and Ward (Fig. 2, Plate XIV.).

General Description.—The country is rough and mountainous, forming a part of the foot-hills of the Rocky Mountains. It lies at altitudes varying from 6,500 to 8,500 feet above sea-level. There are in most places good main roads, constructed and maintained by the county authorities, connecting the various mining-districts, and the mines maintain the wagon-roads in good condition.

Geological Formation.—The geological formation of Boulder county is of a very complex nature, and shows the intimate relation between the structure of the country-rock and of the ore-bodies. The country-rock is a coarse-grained granite, in some places metamorphosed into gneiss, and in others into mica-schist. The metamorphism is often so great as to have almost completely

obliterated the original structure of the rock. Through the granite, at different periods of geological time, were extruded such volcanic rocks as andesite (sometimes a breccia as at Cripple Creek), rhyolite, trachyte and phonolite, the latter often forming dykes. Dykes of "pegmatite" (a variety of orthoclase or potash-felspar) are also a prominent feature of the telluride belts. The eruptive nature of the country-rock is shown by the persistent association of fluorspar (fluoride of lime), with the ore-bodies. In the case of telluride-ores, this frequently makes beautiful mineral-specimens.

FIG. 6.—VIEW OF THE SPRINGDALE DISTRICT.

Lodes.—The lodes, where permanent in depth, are either of the contact, or the true-fissure character. Owing to the extremely disturbed nature of the surrounding country their strike is most irregular, and no general rule can be given. The same may be said for the dip, which varies from as little as 18 degrees from the horizontal, to almost perpendicular. The lodes vary in width from merely a knife-blade to 13 feet and more. The rich ores often are to be found in shoots, which are irregular both in occurrence and extent. Segregated veins also occur in considerable abundance, and it is the instability of these, with the loss and disappointment which they have caused, that has in a great

measure tended to give the gold-mines of Boulder county an indifferent repute. Also, until within the last few years, Boulder county has been the happy hunting ground of the "process man," and has indeed been not inaptly termed "the cemetery of fake process."

Ores.—The ores of Boulder county are of two classes, (1) free-milling gold-ores at the surface on the oxidized outcrop, changing into sulphide-ores in depth, and (2) telluride-ores. The veins of the latter class appear to be the more recent in age of deposition.

A little native copper and green carbonate are occasionally found associated with the oxidized ores.

The sulphide-ores consist of auriferous copper- and iron-pyrites, galena, and blende. The ordinary treatment of sulphide-ores comprises concentration, and shipment to the smelter.

The telluride-ores are calaverite, sylvanite (as at Cripple Creek), and petzite. Some of the richest and most important mines of Boulder county are situated in the neighbourhood of Springdale and Jamestown (Fig. 1, Plate XIII.).

Size of Claims.—The mineral claims of Boulder, Gilpin, Clear Creek, and Summit counties, Colorado, are 1,500 feet long by 150 feet wide. For the rest of Colorado, and for North and South Dakota, the dimensions are 1,500 feet by 300 feet. In all other parts of the United States, claims comprise 1,500 feet by 600 feet.

Golden Age Mine.—The Golden Age mine is one of the richest and most notable mines of Boulder county, and is situate halfway between Springdale and Jamestown, being about 2 miles from either place. It lies at an elevation of 7,500 to 8,500 feet, and consists of six claims, namely, the Golden Age, Sentinel, Rambler, Boston, Terrible, and Hurricane; together with the Sentinel and Boston mill-sites, of 3 and 5 acres respectively. The mine was discovered in 1874 by a half-breed nicknamed "Indian Jack," and has been worked more or less intermittently ever since. It was originally worked as a free-milling mine, and the ore treated at a mill of 25 stamps (at Jamestown), driven by water-power.*

* In addition to personal observation, the writer is indebted for information to a report made by Mr. Ernest Le Neve Foster, of Denver, in 1897; to Prof. Arthur Lakes' book on *Prospecting for Gold and Silver in North America*; and to a paper by Mr. J. B. Farish, *Trans. American Inst. M.E.*, 1891, vol. xix, page 547.

The formation of the ore-bodies in the Golden Age mine is extremely complicated; and it is probable that there exist at least four distinct lodes, of which the two principal ones will be described.

The Golden Age lode is a contact-vein of free-milling gold-ore, carrying specimens of native gold in places, and changing in depth into sulphide-ores, namely, iron-pyrites, galena, blende and chalcopyrite. The Sentinel lode, of more recent age, is also a contact-deposit, and carries free gold, and high-grade telluride-ores.

FIG. 7.—VIEW ON JAMES CREEK, JUST BELOW THE STANDARD MILL.

The Golden Age vein, from which the group of mines takes its name, strikes north 70 degrees east, and dips 45 degrees southward. It occurs in chutes along the contact of a quartz-porphyry dyke with the granite and gneiss, which form the main features of the country-rock of the district. At a depth of 100 feet, the lode is split into two branches by this dyke, known respectively as the hanging-wall and foot-wall streaks. The dyke at this point varies in width from 8 to 50 feet, but may for the most part be treated as low-grade vein-matter, as it is mineralized. The

hanging-wall streak continues into the dyke, but with porphyry instead of granite walls, until a depth of 330 feet is reached. The foot-wall streak contains most base metal of the two streaks. The dyke is much decomposed in the upper workings, but in the lower it is less acted upon, and contains a considerable quantity of iron-pyrites. The true lode-stuff of both the hanging-wall and foot-wall streaks is, however, a hard white vitreous quartz, wherein the gold occurs in a metallic state, in sizes varying from coarse grains to nuggets of several ounces, forming the rich specimens for which the mine is locally famous. A specimen found some years ago contained 70 ounces of gold. The Golden Age vein carries no telluride-ores. It is richest in granitic and schistose rocks, and poorest when passing through the porphyry-dyke. The width of the lode proper varies from 3 to 6 feet.

The Sentinel lode and other tellurium-veins of this mine differ entirely in their structure from the Golden Age vein. Their gangue is the characteristic bluish horn-quartz of the telluride-ores of Boulder county, with chalcedony-quartz crystals, and finely disseminated pyrites. The telluride-ores are sylvanite and petzite. The crossing of the Golden Age and Sentinel veins is very clearly marked, the former being slightly faulted (Fig. 3, Plate XIV.). The Sentinel vein runs north-east and south-west and dips 70 degrees southward, thus crossing the Golden Age both on the strike and on the dip. The Sentinel vein varies from 2 to 4 feet in width. A specimen of telluride-ore, 2 pounds in weight, from the Sentinel lode, contained gold to the value of £47 (228 dollars).

The main hoisting-shaft of the mine is sunk from the surface, on the highest point at the top of the hill, on the dip of the Golden Age vein to a depth of 460 feet, at which depth it is connected by an uprise of 240 feet on one of the telluride-veins, with the tunnel-level (Fig. 4, Plate XIV.).

There is also a tunnel that intersects the Golden Age vein at 800 feet in depth on its dip. This tunnel cuts the Golden Age vein at 460 feet, and the Sentinel vein at 650 feet respectively from its mouth. From the tunnel about 5,000 feet of drifting have been done on the various lodes, and a large amount of irregular stoping—mostly over-hand. An inclined-shaft has been sunk on the dip of the Sentinel vein from the tunnel-level for a depth of 130 feet, two levels have been driven 45 feet apart, and a little stoping has been done.

Owing to the pockety nature of the lodes, and the irregular system, or rather want of system, upon which this mine has been worked, it is difficult to compute the average value of the ore. Considerable quantities of extremely high-grade ore, containing both free gold and telluride, have been, and are still being extracted. The very rich ore is amalgamated by hand on the mine and retorted, and the remainder is shipped to the smelters. The gold sent to the Denver Mint runs from 900 to 960 fine. Throughout the mine, the high-grade ore may be said to run from 200 to 300

FIG. 8. VIEW OF OPEN CUT ON THE STANDARD MINE. ×× SHEWS THE HANGING-WALL; AND THE MAN IS STANDING ON THE FOOT-WALL: THE DIP OF THE VEIN IS ABOUT 20 DEGREES.

ounces of gold per ton, and the so-called low-grade ore from $\frac{1}{2}$ to 1 ounce. It does not pay at present to ship ore of lower grade than 2 ounces per ton.

The output of the Golden Age mine for the past eleven years has been as follows:—

	Dollars.	£
1889	600,000	125,000
1890 to 1894	65,000	13,500
1895 to 1897	85,000	17,800
1898 and 1899	50,000	10,400
	800,000	166,700

For the greater part of the time, the mine has been worked on a system of leasing (or tributing), consequently hardly any of the dead-work (or unproductive mining) necessary for proper development has been done, and the mine has not been opened up in a systematic manner for the economical handling of large quantities of ore.

There is a large quantity of comparatively low-grade telluride-ore, varying from ½ ounce of gold per ton and upwards in value on the dump awaiting economical local treatment. The railway-freight on this ore renders any other course unprofitable. At

FIG. 9.—VIEW OF THE AERIAL TRAM-ROAD FROM THE STANDARD MINE TO THE MILL, ABOUT 1 MILE.

Cripple Creek, it is the general practice to chlorinate at central works ores varying from ½ ounce to 2 ounces per ton in value, all below that value being cyanided, whilst the higher grades are shipped direct to the smelter.

Grand Central Mine.—The Grand Central mine and its extension the Big Blossom, are situated near the Golden Age mine, about 7,350 feet above sea-level. There are five well-defined lodes, of which four, containing telluride-ore, cross and recross

each other on their strike in a somewhat uncommon manner. Some of the lodes have been very considerably heaved in places, and gouge (or selvage), and slickensides are of frequent occurrence. It is presumed that these lodes will unite in depth into one or two large ore-bodies. At present, the workings are chiefly confined to the upper levels, from which for some years past considerable quantities of shipping-ore have been extracted. One of the telluride-lodes has been sunk on for 150 feet, but these workings are now under water. It is supposed that the main lode of the Standard mine passes into the Grand Central mine in

FIG. 10.—VIEW OF THE STANDARD MILL.

depth. The Caledonia and Mother-of-gold mines in this neighbourhood have also considerable showings of telluride-ore.

Standard Mine.—The Standard mine comprises seven mineral claims, namely the Standard, Pennant, Outpost, Mammon, Ocean Wave, Gold Pilot and Golden Siphon, together with a mill-site of about 4 acres. It is situated at an altitude of 7,650 feet above sea-level. This mine has been equipped, and is being developed, in a substantial and minerlike manner, forming thereby an example to the mines of Boulder county. There are two distinct ore-bodies, namely the Standard and Ocean Wave lodes.

The Standard lode strikes north-west and south-east, dips 20 degrees southward, and varies from 6 to 10 feet in width, the average width being 8 feet. Its value runs from 3 to 9 dwts. the general average being 4½ dwts. There is a pay-streak on the foot-wall of the lode, varying from 6 to 18 inches in width of sulphide-ore (galena and iron pyrites), running from 2 ounces of gold per ton and upwards. This ore brings the mean value of the whole ore-body up to about 6 dwts. per ton. The Standard lode has been worked by an open cut at the surface (Fig. 8), and is now being

FIG. 11.—VIEW ON THE ROAD TO GLENDALE.

opened up by a series of four drifts. The country-rock is andesite, in places a good deal decomposed, and so mixed up with lode-stuff that it mostly carries some value, from 1 dwt. per ton and upwards. The ground is easy for working, and stands well with but little timber. The lode is situated on the side of a large hill, its apex outcropping near the top. There is a length of over 1,000 feet on the dip of the lode, which can be worked by crosscut-tunnels before water-level is reached.

The Ocean Wave lode runs counter to the Standard lode, striking north-east and south-west, and dipping westward 42

degrees. It averages 4 feet in width, and has been but little explored.

There is 120 feet head to the mill, which is driven by a Pelton wheel (6 feet in diameter) developing 50 horsepower. The pipe-line to the mill is 4,500 feet long. The mill is 975 feet below the mine. The ore is taken from the mine to the mill by 4,800 feet of single-rope aerial tramway (Fig. 5, Plate XIV.). This was a difficult piece of work, the hillside in places being most precipitous. The highest derrick (or standard) is 120 feet and the longest span 738 feet. The carrying capacity is 12 tons per hour (Fig. 9).

The mill contains 20 stamps of 850 pounds falling weight, suspending Challenge feeders, copper-plates, Wilfley tables, and the usual mill accessories. The water-power not being available on account of frost during about two of the winter months, a 50 horsepower engine is used as an auxiliary for driving the mill (Fig. 10).

This plant was erected for the treatment of the free-milling ore from the oxidized outcrop of the Standard lode, but now that sulphide-ore has been reached in depth, difficulty has been experienced in saving the gold in the mill. It has consequently been decided to abandon amalgamation, and to substitute direct cyaniding of the ore. It was found by experimenting on samples of 2 tons that by crushing the ore and passing it through screens of 20 meshes and using a 0·25 per cent. solution of potassium cyanide, that 80 per cent. of the gold can be extracted in 96 hours; and by crushing through 30 meshes, 85 per cent. can be extracted. The same result can be obtained with a 0·5 per cent. solution and 20 meshes, while crushing to 30 meshes and using 0·5 per cent. solution showed 95 per cent. gold-extraction in 96 hours. The estimated cost of vats, etc., to treat 100 tons of ore daily is £1,000 ($5,000); and, if rolls have to be substituted for the stamps, the cost will be £5,000 ($25,000).

Nugget Mine.—The Nugget mine, located between Springdale and Glendale, at an altitude of 8,100 feet, consists of six mineral claims. The country-rock is granite, interspersed with various eruptive rocks classed in this district under the generic term of porphyry.

The lode is a well-defined fissure-vein with clean walls; the width varies from 9 to 13 feet, and near the surface it is 18 feet

wide, at one place. Up to the present time, the bulk of the ore has been free-milling, but there are indications that telluride-ores will be found at no great depth. The ore is carted to a custom mill, driven by water-power, at Ravena, 4 miles distant, and yields from ½ ounce to 13 dwts. of gold per ton over the plates.

Invincible Mine.—The Invincible mine is located immediately outside Jamestown. The telluride lode is at least 8 feet wide, of which 4 feet is high-grade ore of an average value of 3 ounces per

FIG. 12.—VIEW OF THE TAIL HOLT MINE.

ton. The country-rock is granite, mixed with porphyry, overlaid in places by limestone, and mixed with the fluorspar gangue so often associated with the telluride-ores of Colorado. At present, the low-grade ore, from ¾ ounce per ton and downwards in value, is sorted out, and thrown on to the waste-dump, for want of economical methods of local treatment.

Smuggler Mine.—The Smuggler mine comprises six claims, and is situated at Ballarat, 4 miles distant from Jamestown. It has been worked intermittently for the past 20 years, mostly by

leasers, and is stated to have produced during that period ore to the value of $2,000,000 (equivalent to about £400,000). The lode is a fissure-vein containing high-grade telluride-ores, mostly sylvanite. The country formation is mica-schist and other igneous rocks of the district. The pay-ore varies from a few inches to 4 feet wide. The main shaft has been sunk from the level of the

FIG. 13.—VIEW OF THE HOISTING SHAFT AT THE TAIL HOLT MINE.

top main drift for 625 feet on the dip of the lode. This depth makes the Smuggler the deepest mine in Boulder county.

There are other telluride-ore mines in the vicinity of the Smuggler mine.

Mr. E. P. Jennings gives the following analysis of a typical specimen of high-grade sylvanite ore from the Smuggler mine* :—

* *Trans. American Inst. M.E.*, 1879, vol. vi., page 506.

Tellurium	28·16
Gold	10·04
Silver	4·03
Zinc	0·31
Silica and silicates	55·79
Ferric oxide and alumina	1·36
Cobalt and lead	traces
	99.69

Specific gravity, 3·565

The above analysis corresponds closely with the formula $(Au\ Ag)_2\ Te_3$.

FIG. 14.—VIEW OF THE MONTGOMERY WHIM AT THE TAIL HOLT MINE.

Tail Holt Mine.—The Tail Holt is a nicely equipped little mine, situated at Glendale (Figs. 12 and 13). The vertical shaft has been sunk to a depth of 100 feet, and the telluride-lode is 1½ feet wide. This mine has a "tunnel right," namely, the right to put in a cross-cut tunnel to cut the lode in depth. Fig. 14 shows the Montgomery horse-whim at this mine: it is light, strong and durable, being constructed entirely of wrought-iron and steel.

Water.—As will be seen by reference to the general map of the district, the mining camps of Boulder county are excellently watered, and ample water is usually available for power in the vicinity of the mines (Fig. 2, Plate XIV.).

Timber.—Most of Boulder county being situated below the timber-line (about 9,000 feet above sea-level), it is fairly well timbered, mostly with spruce and pine. Generally speaking, timber for mining and rough building purposes, as well as for fuel, can be obtained without difficulty. Firewood costs 12s. 6d. (3 dollars) per cord, as against £1 9s. 2d. (7 dollars) per ton for Colorado steam-coal, delivered on the mine. This coal comes from the Marshall coal-field, some 20 miles distant by rail from the town of Boulder, and is of fair quality. The average price of coal at Cripple Creek is 17s. 2d. (4·12 dollars) per ton delivered.

Labour.—The comparative rates of daily wages at the mines of Boulder county and those of Cripple Creek are:—

Class of Workmen.	Boulder County.		Cripple Creek.	
	Dols.	s. d.	Dols.	s. d.
Mine-bosses	5·00	20 10	5·00	20 10
Millmen	5·00	20 10	—	—
Amalgamators	5·00	20 10	—	—
Miners	2·50	12 11	3·50	14 7
Machine-drillmen	—	—	4·00	16 8
Engine-drivers	3·50	14 7	4·00	16 8
Firemen	3·00	12 6	3·50	14 7
Mechanics	4·00	16 8	3·75	15 7
Fitters	4·00	16 8	3·75	15 7
Carpenters	3·00	12 6	3·50	14 7
Blacksmiths	3·50	14 7	3·75	15 7
Surface-hands	2·00	8 4	3·00	12 6

A working day at the surface is 10 hours, whilst underground work is carried on in three shifts of 8 hours each. Mechanics' wages are slightly higher in Boulder county than at Cripple Creek, on account of the difficulty in obtaining suitable men. Otherwise the scale of wages is mostly lower, on account of the more pleasant surroundings and the comparative cheapness of living. It is probable, however, that when mining operations on a large scale are started in Boulder county, a miners' union will be formed, and much the same rates will come into force as at Cripple Creek.

Transport.—Freight on ore or supplies from Springdale to Boulder is 16s. 8d. (4 dollars) per ton, and from Jamestown usually a trifle more. When the teamsters can get return freights, slightly lower rates are generally obtained either way (Fig. 16). From Boulder to Denver, the railroad freight is 4s. 2d. (1 dollar) per ton on lots of 20 tons and upwards, and below that weight 5s. 2d. (1·25 dollars) per ton.

Smelting Charges.—Smelter rates on Boulder county ores are at present high, chiefly on account of the small lots in which they are supplied. The charge is £1 17s. 6d. (9 dollars) per ton on sulphide-ores, £2 10s. (12 dollars) per ton on telluride-ores, and 95 per cent. of the gold is paid for by assay-value. Cripple Creek rates are, on high grade ores, £1 7s. 1d. (6·50 dollars) and on the low-grade ores £1 9s. 2d. to £1 13s. 4d. (7 to 8 dollars) per ton.

There are three smelters in Denver, the Omaha and Grant, the Globe (American Smelting Company), and the Argo (Boston and Colorado Smelting Company). The two former works smelt to a

FIG. 15.—TYPICAL TRIBUTE WORKINGS, AND THE OLDEST TRIBUTER (80 YEARS OF AGE) IN BOULDER COUNTY.

lead-base, namely, to base bullion (subsequently shipped to Omaha and to Jersey City to be refined), and the latter to a copper-base, namely, matte (subsequently refined by a modification of the Ziervogel sodium hyposulphite process).

There are two public sampling-works at Boulder, those of Messrs. W. J. Chamberlain and Company, and the Kilton Reduction Company, each of 75 tons daily capacity.

Discovery of Telluride-ores.—Telluride-ore had been previously known at Georgetown, Eldorado county, California, and was first discovered in Colorado at the Red Cloud mine, Gold Hill,

Boulder county, in 1871. It was identified as petzite by Dr. Anton Eilers.* The average value of several tons ran from 3½ to 20 ounces of gold per ton. The highest assay obtained for gold was 978 ounces and for silver 9,304 ounces per ton.

Conclusion.—Unfortunately, owing to a heavy fall of snow, the writer was unable last year to visit the promising sulphide-ore camps at Eldora, Gold Hill, Salina, Sunset, Sunshine and Ward; these all being situated at a considerably higher altitude than those described.

FIG. 16.—MULE TEAM USED IN THE MOUNTAINOUS DISTRICTS OF COLORADO.

The writer is indebted for the photographic views and for much valuable information and assistance to Colonel Edward E. Britton, late of the 114th New York Infantry Regiment.

The PRESIDENT (Mr. H. C. Peake) moved a vote of thanks to Mr. F. Owen for his interesting paper.

The Rev. G. M. CAPELL seconded the resolution, which was cordially approved.

Mr. W. H. BLAUVELT's "Description of a Plant of Semet-Solvay Bye-product Coke-ovens at Wheeling, West Virginia, U.S.A.," was read as follows:—

* *Trans. American Inst. M.E.*, vol. i., page 316.

To illu[illegible] of Boulder County, Colorado, U.S.A."

FIG. 1.

MAP

SHEWING THE MINING CLAIMS

IN THE

SPRINGDALE DISTRICT,

BOULDER COUNTY,

COLORADO, U.S.A.

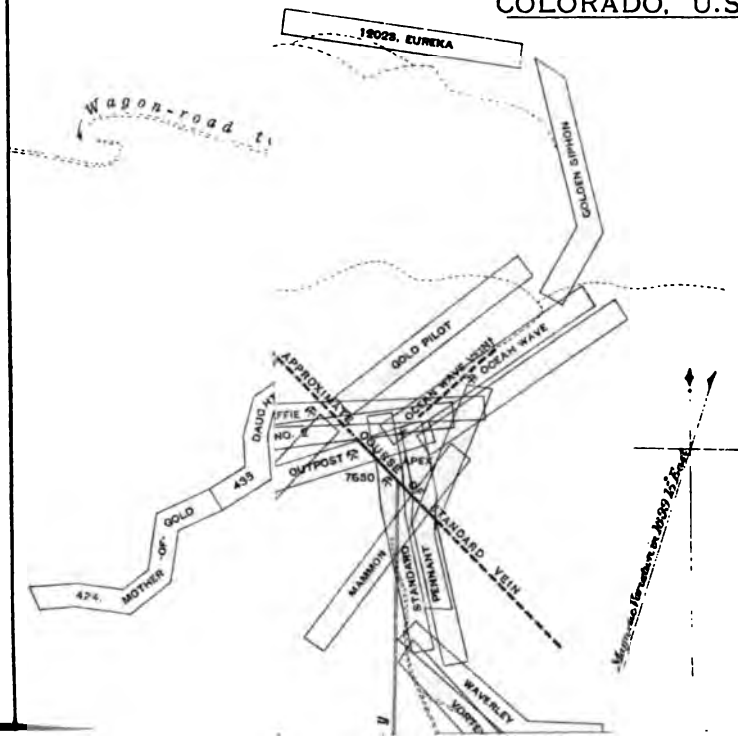
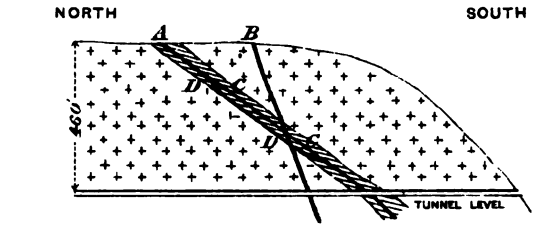


FIG. 3.—APPROXIMATE TRANSVERSE SECTION,

SHOWING THE CROSSING OF THE GOLDEN AGE AND SENTINEL LODES.



REFERENCES.

QUARTZ PORPHYRY

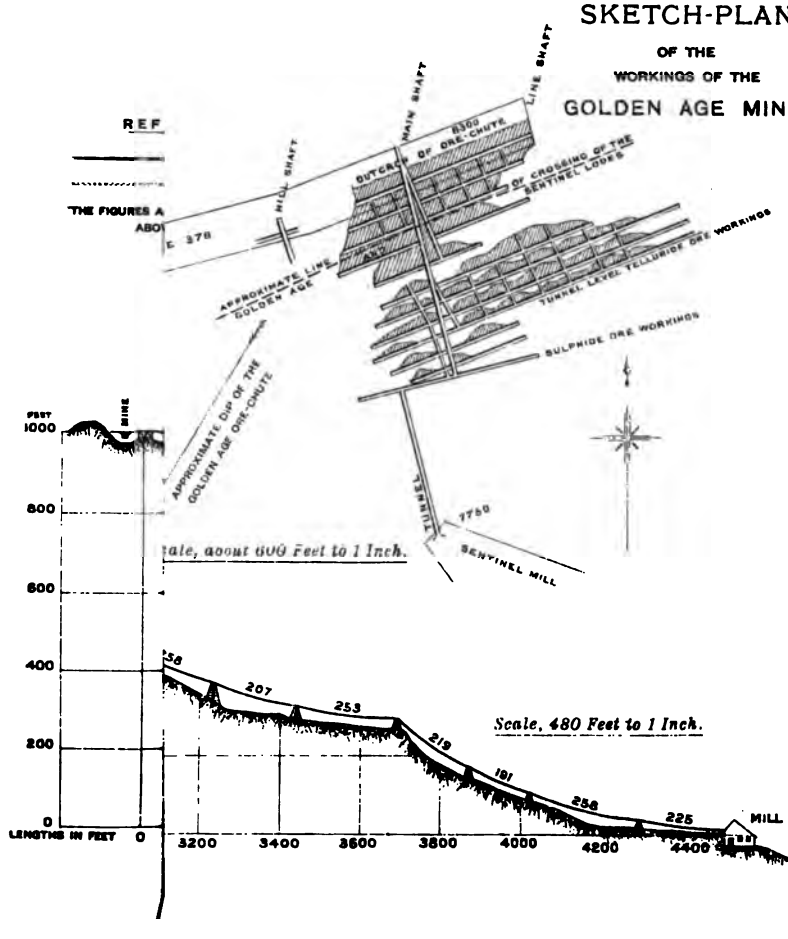
GRANITE AND GNEISS

A GOLDEN AGE LODE
B SENTINEL LODE
C HANGING-WALL STREAK OF GOLDEN AGE LODE
D FOOT-WALL STREAK OF GOLDEN AGE LODE

Scale, 600 Feet to 1 Inch.

FIG. 4.

SKETCH-PLAN OF THE WORKINGS OF THE GOLDEN AGE MINE.



DESCRIPTION OF A PLANT OF SEMET-SOLVAY BYE-PRODUCT COKE-OVENS AT WHEELING, WEST VIRGINIA, U.S.A.

By WILLIAM HUTTON BLAUVELT.

The bye-product retort coke-oven has found the road to general favour a much more difficult one in both Great Britain and the United States than in continental Europe. The reason for this is found in the fact that while many of the coals, particularly those of France and Belgium, are so low in volatile matter as to make it necessary to use a retort coke-oven in order to produce any coke at all, both Great Britain and the United States possess large deposits of coal that are particularly adapted to the peculiar conditions of the beehive coke-oven, and these produce in the beehive-oven coke of a quality that cannot be excelled for furnace and foundry use, and with a comparatively small loss of fixed carbon. It is not to be wondered at, therefore, that the coke-consumer has been slow to accept as a fuel of equal value for metallurgical purposes a coke which lacks any of the qualities of the beautiful silvery product to which he has been long accustomed.

But the growing number of retort coke-ovens in both Great Britain and the United States indicates clearly that this natural prejudice is becoming a thing of the past, and that retort-coke is taking its proper position as a metallurgical fuel. In the United States there are a number of representative plants which use retort-coke either entirely or in part, while maintaining, and in some cases bettering their high record for low fuel consumption and large production.

In every case, the retort-coke is put on a perfectly equal footing with the best beehive-coke, and where the retort coke-ovens have not sufficient capacity to supply entirely all of the furnaces, it is the usual course to change the proportions of retort-coke and beehive-coke on any furnace, as convenience requires, the changed proportions producing no effect on the operation of the furnace. At one furnace-plant, where retort-coke and beehive-coke, both

made from Connellsville coal, are used, it is always found necessary to somewhat increase the burden, or the proportion of ore to coke, when the proportion of retort-coke is increased in comparison with beehive-coke.

This point has been somewhat elaborated in order to bring out the fact that however one may theorize regarding the respective merits of "carbon glaze," "more dense cellular structure," "slow coking" or "rapid coking," the test in the blast-furnace, which after all must be the final one, shows that the two cokes are essentially of equal value when made from a coal suitable to use in the beehive coke-oven. This has been shown under such varying circumstances of locality, management, furnace-mixture or other points that might affect the comparison, as to convince anyone who will take the trouble to investigate that the only question remaining is the comparative economy of production of the two cokes.

The comparisons above outlined have all been between beehive-coke and retort-coke produced from coal suitable for making beehive-coke. Of course, there are many other coals, both in Europe and the United States, which do not work satisfactorily in the beehive coke-oven, but which give excellent results in the retort coke-oven. This is notably the case on the continent of Europe, as mentioned above, and also in some important coal-producing localities in the United States.

In the vicinity of Pittsburgh, Pennsylvania (the largest iron-producing centre in the United States), the beehive coke-oven is of course in a very strong position, on account of the special fitness of the coal worked from the Connellsville seam (which supplies the coking-coal for the whole region) to the processes of the beehive coke-oven. But it is mainly in this region that the retort coke-oven has established itself, and the growth attained is not inconsiderable, in view of the difficulties which the "infant industry" has had to encompass.

The plant of Semet-Solvay ovens at Wheeling, West Virginia, is the fifth installation of bye-product ovens in the vicinity of Pittsburgh, and it is also the largest, having a capacity of 475 tons of coke per day. (Coke in America is always measured by the ton of 2,000 pounds.)

The general design of the Semet-Solvay coke-oven has already

been described before the Institution,* nevertheless it might be well to outline the principal features of its design. Figs. 1 and 2 (Plate XV.) are longitudinal and cross-sections of the coke-oven, showing that it is of the horizontal flued type, with the distinguishing characteristic of a flue-system entirely independent of the main-structure of the oven. This independence of the flues has several important advantages. The weight of the roof, and any coal-cars or other weights that might be carried on the top of the ovens, is borne on the solid walls (18 inches thick) placed between the rows of flues, making it possible to have the flue-walls much thinner than in any other system without danger of rupture, as they do not support any weight while in a highly heated condition. This thinner wall permits of a temperature 300 or 400 degrees Cent. lower in the flues than in the types of ovens which have thick flue-walls, while maintaining the same temperature within the coking-chamber. The flues, being independent of the main structure of the oven, are perfectly free to contract or expand, as the temperature is varied by the introduction of a charge of coal, and its gradual heating up to the point of highest temperature; and the space between the main arch of the roof, and the arch over the oven-chamber, which is usually packed with mineral-wool, gives ample room for the movement of the tile, without affecting the main brickwork. This renders the latter free from all racking strains, and makes it as permanent as any piece of fire-brickwork may be. The horizontal flues permit of absolute control of the temperature in each portion of every flue, and of their inspection throughout their whole length at any time, by simply shutting off the gas from the flue which is to be examined. This permits of the flues being kept perfectly free of soot, and prevents the possibility of their being overheated. It also permits any leak from the oven-chamber to the flue being instantly detected, and readily stopped.

In the development of the horizontal flue-oven, it has been kept carefully in mind that even with the most careful construction and manipulation a retort coke-oven cannot be kept perfectly air-tight, and that it is in fact in communication with the outside air. If the exhauster which removes the gases from the ovens runs at too high a speed, air is drawn into the oven, and if too little suction be used the distillation of the coal will force the gases out through the ends of the ovens and into the flues. Since

* *Trans. Inst. M.E.*, 1895, vol. ix., page 54.

the coking-chamber cannot be sealed from the outside air, it is apparent that at varying heights from the floor of the oven the tension of the gases varies, the greatest pressure being at the top. This difference of pressure is practically illustrated by the fact that when the exhauster is run a little too slowly, thereby increasing the pressure in the coking-chamber, smoke always appears first from the top of the oven, and can only be forced from the bottom by a further increase in pressure. It follows, therefore, that to prevent the escape of the gases from the coking-chamber into the flues, with the resulting loss of bye-products, not only must the tension of the gases in the flue be the same as that in the oven, but it must vary in different portions of the flue-system so as to correspond with the density in adjacent parts of the coking-chamber. In designing the Semet-Solvay coke-oven, the flues have been so proportioned that as the gases travel through them they are at all times, from the point of admission until they reach the chimney-flue, at the same relative tension as the gases in the coking-chamber at the same level or distance above the floor. It then only remains to adjust the balance between the flue and the oven, by the proper regulation of the chimney-damper and exhauster, in order practically to prevent the loss of the gases distilled from the coal, or their combustion by air drawn into the coking-chamber.

The thin flue-walls and the accurate control of the heat permit of very rapid coking, so that the most modern Semet-Solvay coke-oven has an output of 1,650 to 2,100 tons of coke per year per oven, the amount depending on whether coal low or high in volatile matter is used.

The recuperation-system has been carefully developed in the Semet-Solvay coke-oven. By this system, the air for the combustion of the gas is heated to a temperature amply high for the economical production of the temperature required in the flues, and this is obtained by a simple and inexpensive system of air-flues in the bottom of the coke-oven, which takes the heat from the escaping products of combustion, without any attention on the part of the operatives. The waste-gases, after heating the air, supply just about enough heat to furnish steam, if economically used, for the operation of the plant, and the concentration of the ammonia-liquor. This fact makes the plant self-contained, and at the same time ensures economy of heat-consumption, and the greatest possible amount of surplus gas from any given coal.

A general view of the oven-plant at Wheeling is shown in Fig. 4. The plant is located adjacent to the blast-furnaces of the Riverside department of the National Tube Company, who are large manufacturers of pig-iron, steel-pipes, boiler-tubes, etc., and furnishes them with their supply of coke. The general arrangement of the plant may be readily seen from the accompanying plan (Fig. 3, Plate XV.), which shows also the coke-bin at the furnace stock-house, into which the coke is delivered, to be drawn into the furnace-bogies. The arrangement of coke-handling ensures a minimum breakage, as after it is pushed out upon the inclined bottom-quenching car it is drawn by locomotives and a winding-engine to the top of the coke-bin, and discharged into the bin by simply opening the gates at one side of the car. The bins are arranged so that the coke slides rather than drops into them, and is drawn out below into the furnace-bogies through a shute with a screen-bottom. This screen effectually removes the breeze-coke, which fills into a small hopper at the back of the shute, whence it is removed from time to time. The coke by this method is not handled with forks, and reaches the furnace with the least possible labour.

The usual arrangement of 60 coke-ovens in a line, on each side of the building in which the bye-products are collected from the gas, is of necessity modified in this plant, as shown on the plan, to suit the space available, but this in no way affects the operation of the plant.

Connellsville coal is used in the manufacture of the coke, and is delivered to the coal-bins over the ovens by means of crushers, elevators and conveyors of the link-belt system. The bins hold several days supply of coal, and in addition a reserve storage of 4,000 tons is carried, to provide against prolonged interruptions of the daily supply. The coal is handled into and out of this storage-pile by a bucket-conveyor passing over the apex of the pile, and returning through a tunnel beneath. From the bins over the ovens the coal is drawn into lorries which run over the ovens, and from which the ovens are charged by means of charging-holes in the roof in the usual manner. The coking-time at this plant varies from 22 to 24 hours. If the ovens be kept at a proper heat, the best coke is produced from Connellsville coal in these ovens in rather less than 24 hours.

FIG. 1. VIEW OF A PLANT OF SEMET-SOLVAY BYE-PRODUCT COKE-OVENS, AT WHEELING, WEST VIRGINIA, U.S.A.

The water-supply is derived from two sources: most of the water comes from 2 artesian wells, operated on a modification of the Pohle system. As this system is perhaps unfamiliar to some of the members, a brief description of these wells may be of interest. Besides the ordinary pipe-casing of the well, which is 8 inches in diameter, another pipe (1¼ inches in diameter) is suspended in the centre. Air under a pressure of about 110 pounds per square inch is forced down the smaller pipe, and mingling with the water at the bottom of the well, rises through the outer pipe. The mixture of air and water is of course lighter than air alone, so the pressure of the surrounding water in the earth at the bottom of the well forces the lighter column to a height above the natural level proportional to the difference in weight. Experiment shows that, to obtain a maximum flow from a well by this system, the submergence of the air-pipe should be about 1½ times the vertical distance from the level of the water in the well to the point of delivery, or the distance that the water is lifted. The Wheeling wells are 300 feet deep, and deliver water to a height of 60 feet above the surface. The air-pressure, and other conditions of operation, indicates a submergence of about 220 feet, and that the water is lifted from a point about 80 feet below the surface, or 140 feet in all.

The water obtained from these wells at Wheeling is excellent for cooling purposes, as it varies only about 1 degree Cent. in temperature during the year, averaging about 13 degrees Cent. It is quite hard, however, so that it cannot be employed for boiler-supply or any other use where it will become heated sufficiently to cause deposition of the lime salts. For these purposes, a second supply of soft water is drawn from the Ohio river, which runs close to the plant.

Natural gas was formerly used in the steel-works adjoining the ovens, and the coke-oven gas proves an acceptable substitute. It is used in the heating-furnaces, and under the steam-boilers and galvanizing-pots. A small gas-holder preserves an uniform pressure on the gas, and corrects minor irregularities in the supply. The amount of gas delivered to the works from the coke-oven plant is estimated at from 2,250,000 to 2,500,000 cubic feet per day.

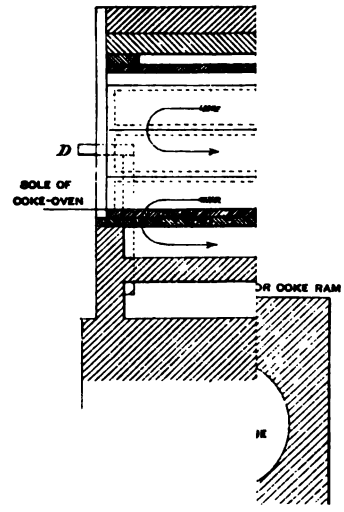
In connection with the delivery of this gas, it may not be out of place to mention a circumstance which the writer has never

been able to account for, although the explanation may perhaps be very simple. Both at the Wheeling plant and at others, it has been noticed and often commented on, that although naphthalene sometimes accumulates in the main gas-pipe conveying the washed gas from the bye-product building to the gas-holder, so as to require steaming out, yet the small service-pipes conveying the gas from the holder to the point of consumption remain free of obstructions, even after several years of service.

A plant for the distillation of the tar produced at the coke-ovens is now under construction, and will soon be in use. The stills will have a capacity of 11,000 gallons of tar per day. Owing to the topography of the country in the vicinity of the coke-oven plant, the location of the tar-stills in relation to the ovens is somewhat unique. The city of Wheeling is built on a long narrow strip of level ground between the Ohio river and a line of steep hills several hundred feet in height, that run approximately parallel to the river for a number of miles. At the oven-site, the steel-plant and ovens, together with the railway and street, occupy the whole space between the river and the hill, leaving absolutely no space for the tar-stills.

In former days, however, a tunnel had been cut through the hill for bringing limestone to the furnace-plant, which preceded the present one. This tunnel had been practically out of use for many years, but it was still in good repair, and by its use an excellent site for a distillation-plant was made available, on the other side of the hill, but distant only some 600 feet from the coke-ovens. The tunnel is at an elevation which permits of easy delivery of the pitch to the railroad by means of tram-cars, and the tar and oil can be handled most conveniently by compressed air from the compressors that operate the artesian wells. The isolated location of the stills prevents danger to the rest of the plant if a fire should occur, while it is near enough to be operated without any extra expense. For the present, only roofing and paving pitch and creosoting oil will be made at this plant.

Regarding the financial side of the operation of this bye-product oven plant, it is only necessary to state that the plant was at first built less than half its present size; and only after a full trial had been made of the value of the coke for the blast-furnace,



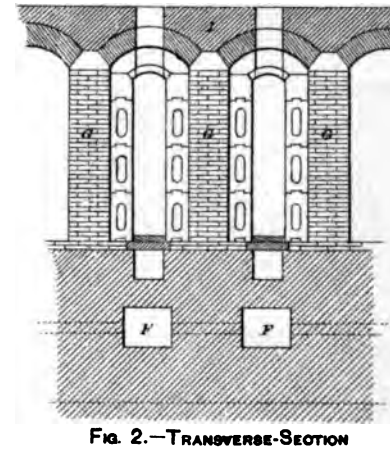
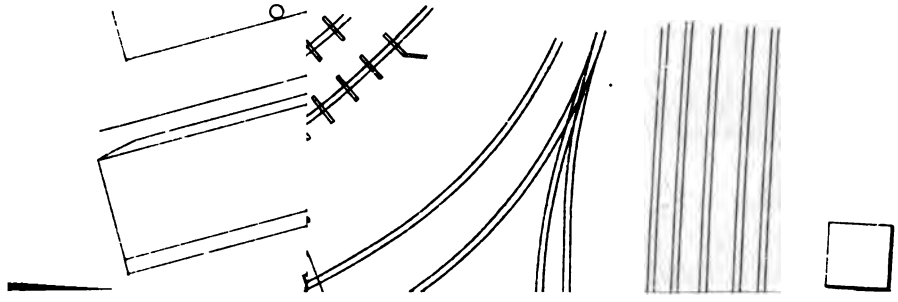


Fig. 2.—Transverse-Section on Line X Y of Fig. 1.



after determining the returns from the bye-products, and completely developing the whole operation, was the additional construction undertaken, which has more than doubled the original size of the plant.

Mr. A. L. STEAVENSON (Durham) said that in 1859 he read his first paper on the subject and since that time he had seen various coke-ovens described, but as time went on he had come to the conclusion that much depended upon the people who make and use the coke, as to whether a system would be a success. In beehive coke-ovens, the coke was cooled in the oven, and as soon as it was slaked it was left for ¼ hour, and the coke became quite dry. But with the Semet-Solvay and other retort coke-ovens, the hot coke was drawn, and when outside, it was watered, and as there was no means of drying it, 5 or 6, or even 10 per cent. of water was found in the coke. Satisfactory coke, as to the moisture-content, was produced at some coke-ovens in Germany, where it was watered by hoses with small nozzles: the coke was expelled from the oven and water was sprayed upon it from fine nozzles, and as soon as the coke was cooled, men, with wooden shoes, went about with watering-cans and when they saw any hot coke, they poured a little water on it. Retort-ovens were being gradually erected, but he had not yet met with a furnace-manager who preferred to use coke made in retort-ovens rather than that made in beehive coke-ovens. In describing the water supply, Mr. Blauvelt stated that a modified Pohle air-lift pump was used to raise water from two artesian wells.*

The PRESIDENT (Mr. H. C. Peake) moved a vote of thanks to Mr. Blauvelt for his interesting paper.

Mr. W. D. WIGHT seconded the motion, which was cordially adopted.

Mr. EMERSON BAINBRIDGE'S paper on "An Electric Pump for Underground Use" was read as follows:—

* *Trans. Inst. M.E.* vol. iii., page 1,096; and vol. xvii., page 584.

AN ELECTRIC PUMP FOR UNDERGROUND USE.

By EMERSON BAINBRIDGE.

In the development of engineering, as applied to mining, there is no doubt that electricity will continue to take a prominent place, especially in the application of power underground, whether for hauling or pumping or ventilating mines, the workings of which are a long distance from the shaft. Whilst the general development of electricity is being checked by the opposition of Parliament to private enterprise as against municipal trading, there is every reason to believe that mining engineers will take advantage of the manifold improvements which are constantly being brought forward.

Pumping underground may be generally divided into three classes:—(1) Pumping by means of an engine placed on the surface; (2) pumping from the bottom of the mine to the surface by means of an engine at the bottom of the pit, which is frequently used as a duplicate of the engine on the surface; and (3) pumping-engines placed underground at a greater or less distance from the shaft to deal with small and large quantities of water in the workings. It is especially under the latter head that electrically-driven pumps have now come into use, and with the enhanced depth of mines there are likely to be increased applications of electricity under the second head.

The mere question of dealing with water by means of a pump need hardly be discussed in this paper, as whether the motive power is electric, hydraulic, steam or compressed air, the efficiency of the pump itself depends mostly upon the design and workmanship. On the other hand, where belting or spur-gearing is not employed, it is of course desirable to use a pump which has a good useful effect at high speeds, and such a pump should be compact and occupy a small space—desiderata which are of great importance in mining operations. During the last few years, the chief

development of electrical engineering has been in the direction of providing efficient steam-plant for producing electric energy, and the resources of mechanical science as applied to economical steam-production have been brought to bear upon this interesting question. It has now been clearly demonstrated that with modern plant electric energy can be produced at a cost of ¼d. per unit,

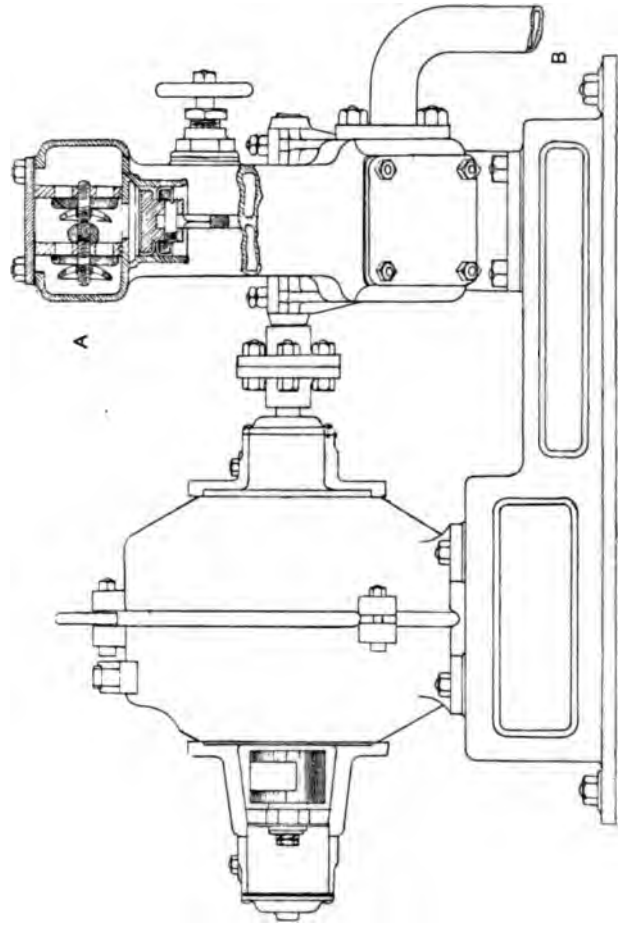


FIG. 1.—SIDE VIEW OF ELECTRICALLY-DRIVEN HATFIELD PUMP.

this being, of course, a much lower figure than the working cost of even the best electric plant at collieries; but in arriving at the cost of electrically-driven pumps, it is fair to assume that such conditions are available.

One of the important objects to be aimed at in pumping is to utilize, in the work done, the largest possible percentage of the

power applied, and in practice there is little doubt that there is a serious waste in the application of steam, wire-ropes, or compressed air in conveying power underground. In fact, whatever difficulties there may have been in the past in economically producing electric power, there is little doubt that ultimately the percentage of power utilized will be greater than in any of the above-mentioned systems.

The subject of economy of power, however, is not by any means the only consideration. The power that a mining

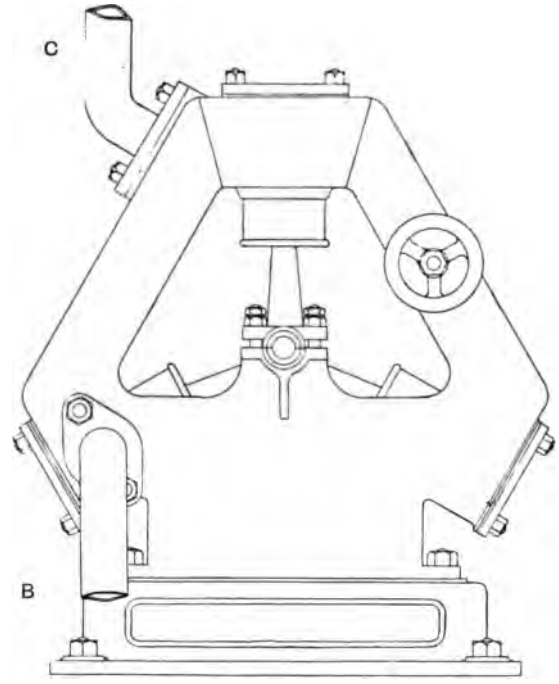


FIG. 2.—END VIEW OF HATFIELD PUMP.

engineer wishes to employ underground should require the least repair and maintenance, and interfere the least with the safe and economical working of the mine. Thus, while compressed air is liable to cause difficulty through defective joints and breakages to pipes; ropes as a driving power are objectionable because of the space that they occupy, their liability to breakage and the general wear-and-tear. It has already been pointed out that the question of the pump itself for underground work is not so important as the general design of the pumping-arrangements. In other words, for mining purposes a self-contained motor, and a quick-

running efficient pump occupying very little space would probably be the form which would find most favour in the eyes of colliery managers.

The Hatfield pump (Figs. 1 and 2) consists of an arrangement of three pump-barrels, arranged round a shaft driven by a motor, the treble form being a triangular casting (of gun-metal in the smaller sizes), and in this casting are formed the pumping chambers and passages. The special feature of this treble pump is the extreme shortness of the stroke, which is about 1 inch, the diameter of the barrels being adapted to the duty to be performed. The pumps are driven at high speed (from 600 to 700 revolutions per minute), and at this speed it is important, of course, to have a form of valve which is able, as far as possible, to resist wear-and-tear. Indiarubber disc-valves, *A*, are used, of the same form as those adopted for high-class fire-engines. One form of this pump is provided with an arrangement for enclosing the pump-barrels, so that no difficulty can arise from dust, etc., the moving parts being altogether protected. The starting of the motor against a head of water is facilitated by the provision of a bye-pass valve between the suction and delivery water-passages (*B* and *C*).

It will at once be seen that the construction of this combined motor and pump is extremely compact and simple. The following table records the weight and dimensions of the combined motor and pump as applicable to various conditions of work.

DETAILS OF THE HATFIELD ELECTRIC PUMP.

Capacity: 100 Gallons of Water lifted per Minute to a Height of	Dimensions of Pump.			Motor.		Total Weight.	Space Occupied.
	Diameter.	Length of Stroke.	No. of Revolut'ns per Minute	Brake Horse-power.	Diameter of Armature		
Feet.	Inches.	Inches.			Inches.	Cwts.	Ft. In.
200	4¼	1	700	9	24	22	3 3 × 3 3 × 3 0
400	4¼	1	700	18	33	34	3 3 × 3 6 × 3 3
600	4¼	1	700	25	39	40	3 9 × 3 9 × 3 6

It will be readily recognized that if the absence of repairs and the efficiency of the pump are as satisfactory as the compactness of the machinery used, the Hatfield pump will be useful and con-

venient for underground work. It may be stated that this pump is also applicable for any pumping, which may be required on the surface; and especially for boiler feed-pumps, in cases where electric power is available.

The general advantages of the Hatfield pump may be summarized as follows:—(1) Exceptional efficiency, in consequence of avoiding the use of gearing and belting; (2) small space occupied; (3) noiselessness in working; (4) steadiness of the stream of water delivered; and (5) economy in the wear-and-tear of the working parts.

Mr. A. L. Steavenson (Durham) remarked that the great feature of electricity was the high speed at which a motor had to run, and when the speed was reduced to the speed for pumping the useful effect was reduced to a low figure.

Mr. S. F. Walker remarked that the useful effect, based upon the horsepower in the water pumped and the brake-horsepower, appeared to be 66⅔ per cent., irrespective of the size of the pump.

Mr. W. D. Wight (Pontypridd) said, supposing the suction-pipe to be empty, with a short stroke there would be great difficulty in catching hold of the water.

Mr. Henry Hall (H.M. Inspector of Mines) said that Mr. Bainbridge had not given any particulars as to the danger of sparking from the motor. He thought from what he had seen of the working of motors that there was a considerable probability of sparking. If the motor was enclosed, some part must be working through stuffing-boxes, and he imagined that a stuffing-box could not be kept sufficiently tight so as to prevent the outside atmosphere entering into the casing of the motor, and if that atmosphere happened to be explosive there would be considerable danger of the outside atmosphere being ignited. Some engineers maintained that an enclosed motor was absolutely safe, but, in his experience it was very difficult to maintain air-tight joints, and the part working through the stuffing-box must, he thought, become loose, in course of time, by constant wear.

Mr. S. F. Walker (London) said that the sparking of electric motors had been fully discussed by Messrs. Heise and Thiem.*

* *Trans. Inst. M.E.*, 1899, vol. xvii., page 88.

These gentlemen had made a long series of experiments, they dealt particularly with the sparking of the commutator and the motor, and they showed conclusively that there was absolutely no danger from sparking. Further, it was wellknown that the construction of dynamos and motors had been enormously improved during the last ten years, and a sparkless dynamo could now be supplied, if required. That is to say, it was sparkless, so long as it was maintained in good order and was not worked much above its full load. It was not a difficult matter to keep a motor in such order as to make it practically sparkless, and by enclosing the commutator within a case, so as to practically cut off the supply of gaseous mixture, the motor became harmless.

The PRESIDENT, in moving a vote of thanks to Mr. Bainbridge for his paper, remarked that he attached very little importance to the danger of using electric motors underground but tnere was much greater risk of sparking from the fracture of the cable, which was much more dangerous than the sparking in an enclosed motor.

Mr. J. GERRARD (H.M. Inspector of Mines), in seconding the vote of thanks, said that from what he had seen in mines in connexion with the use of cables and the danger of short-circuiting, he was not prepared to subscribe to Mr. Walker's conclusion that the risk of sparking was very small. Electricity was a cheap source of power, but from his experience, every care should be taken that the place where the motors were working was free from fire-damp, and to lay the cables, so far as possible, in intake rather than in return air-ways.

The vote of thanks was cordially adopted.

Mr. JOHN MEIKLEJOHN's paper on "The Klondike Gold-fields" was read as follows: —

THE KLONDIKE GOLD-FIELDS.

By JOHN MEIKLEJOHN.

The first rich discovery of placer gold in the Klondike (or more properly known as Troanduick) district was made by George Cormack, who, with a party of Indians, located the discovery-claim about ½ mile below the entrance of Eldorado into Bonanza creek. News of the find became known at the Forty-mile and Circle City

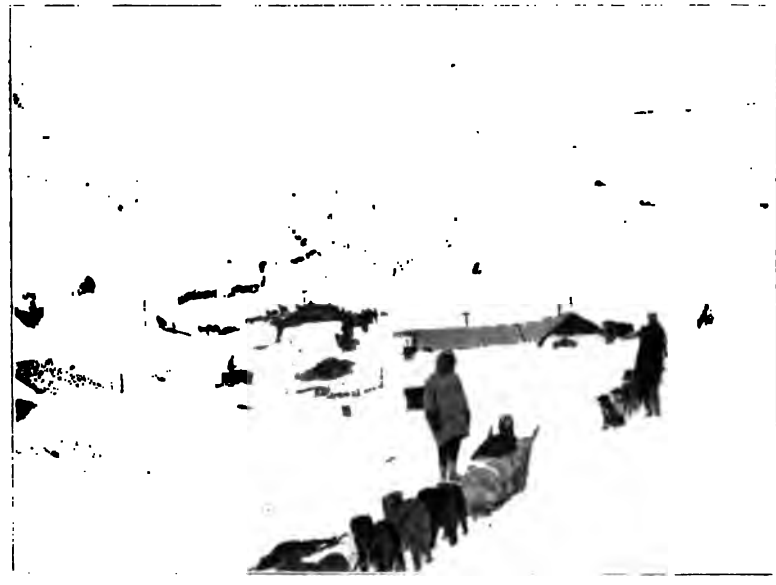


Fig. 2.—Level Part of the Trail, between Skagway and White Pass Summit.

diggings, at that time the only principal paying-camp on the Yukon, and a stampede to the new discovery ensued. The whole length of Eldorado and Bonanza creeks was quickly taken up in claims, and, as room could not be found for all in the valleys of those streams, the creeks heading from the same dividing-range were also staked out (Fig. 1, Plate XVI.).

Work was immediately prosecuted with vigour and the results, especially on Eldorado creek, being surprisingly rich, the news was widely advertized in the summer of 1897 all over the civilized world, and tempted many persons of all ages, professions, and conditions to try their fortunes in this new country. The rush caused by the official news confirming the area and richness of the gold-field is now a matter of history.

FIG. 3.—SCENERY ON THE WHITE PASS AND YUKON RAILWAY.

Several routes were advertized as being practicable, but all more or less involving danger and hardship. Only a few of those who attempted the Edmonton and Teslin river routes were successful in getting through, and all who made the attempt met with hardships and great privation, and many lost their lives. The all-water route *via* St. Michael's is a lengthy one, but it had one virtue in possessing little or no danger for those who took it.

The most popular entrance into the country was either by the way of Dyea or Skagway, both of which places were rival points for transportation to Lake Bennet from which the river-current was followed to Dawson. On leaving Dyea or Skagway for Lake Bennet, the arduous task of climbing a high and rocky mountain-

range was entailed before reaching the water on the other side. A large camp was formed during the winter of 1897-98 at Lake Bennet, and on the ice breaking up in the spring-time the mad rush proceeded down the dangerous river, entailing the loss of much property and many lives before the scene of expected fortunes was reached.

A wonderful improvement has taken place since that period, as a railway now connects Skagway with Bennet, and thence steamers ply to Dawson. Entrance into the country can now be secured

FIG. 4. – MILES CANYON.

with comfort and at moderate expense; and freight is being carried from the Pacific coast to Dawson at 2d. to 3½d. (4 to 7 cents) per pound. Dawson is the distributing centre for the gold-field, and is situated on the banks of the Yukon river, where the Klondike river flows into it. It is 1,700 miles from St. Michael's and 700 miles from Skagway.

The climate is a delicate subject to touch upon, as some curious notions, as applied to Klondike, of that all-absorbing topic have got abroad. The summer commences when the snow melts in the

middle of May, and ends when the frost sets in again towards the end of September. This roughly may be taken as the length of the summer working-season. Autumn and spring are so short-lived that they are scarcely worthy of notice. The summer days follow each other with little or no darkness for a space of about three months, and during the middle of the day the heat is sultry in the extreme. The winter days are not altogether days of darkness, as on the shortest day there is about six hours of actual daylight, although the sun is hidden from view for about three months at that time of year. The official record gives the lowest registered temperature as occurring in January, 1896, namely, 67·9° below zero Fahr. The temperature as officially recorded for the winter 1896-97 is tabulated, as follows:—

Months.	32° and below.	0° and below.	10° and below.	20° and below.	30° and below.	40° and below.	50° and below.	Lowest Reading below zero.
								Degrees.
1896. September	8	—	—	—	—	—	—	—
,, October	27	2	—	—	—	—	—	1·0
,, November	30	23	18	13	7	—	—	38·0
,, December	31	28	19	11	7	2	—	44·5
1897 January	31	27	21	16	13	9	6	55·6
,, February	28	23	23	14	9	2	—	46·0
,, March	30	21	15	12	8	5	3	54·3
,, April...	27	1	—	—	—	—	—	5·0

Nota Bene.—Thermometer readings were taken twice daily, the lowest and highest temperatures being recorded. The figures in the table record the number of times that the temperature was found to be below the specified temperatures at the heads of the respective columns.

With clothing suitable for the climate, the coldest day is endurable, although care must always be taken not to expose recklessly any bare part of the person to the searching frost.

The main gold-producing streams (ranked according to their order of known richness) are:—the Eldorado, Bonanza, Dominion, Hunker and Sulphur creeks. The position of these creeks may be seen on the map (Fig. 1, Plate XVI.).*

The Klondike series is almost entirely composed of schists, and at many points innumerable small quartz-veins or stringers occur between the folia, but they seldom run for more than a few feet

* The map of the Klondike gold-fields is reduced from No. 688 sheet of the *Geological Survey of Canada*, compiled by Mr. J. F. E. Johnson.

before terminating. None of this quartz, so far as the writer has been able to determine, carries more than a trace of gold. The schists are plentifully " peppered " with an abundant supply of sulphides, and it is possible that this, assisted with what may have been concentrated from quartz-veins and dykes in the vicinity, may have some connexion with the gold-deposits in the valleys that seam the country.*

FIG. 5.—DAWSON CITY, LOOKING NORTHWARD.

There is no general distinction between the appearance of one creek and another, so that a general description of one may be taken as covering the whole. The valleys are walled on each side by well-weathered and rounded spurs leading from the dividing range, from which numerous small feeders or tributaries take their source and swell the volume of the larger creeks below. The spurs are sparsely timbered with small-sized specimens of fir, pine and birch, which rarely attain more than 9 inches in diameter, and they constitute the main supply of timber for mining-operations in the vicinity.

The whole surface of the ground is covered with a heavy carpet of moss, averaging about 8 inches in thickness, and this acting as

* *Geological Survey of Canada: Preliminary Report on the Klondyke Gold-fields, Yukon District, Canada.* By Mr. R. G. McConnell.

a shield during the warm weather preserves the ground in its frozen condition. The depth of the frozen surface has not been ascertained. The deepest shaft in 1899 was sunk 187 feet on the hill-side near the mouth of Bonanza creek: numerous shafts on Gold Hill, French Hill and Adams Hill have attained a depth of over 100 feet and in all cases the frozen belt had not been cleared. Occasionally one hears of a shaft being sunk at a shallow depth that had passed through the frozen ground, but it has always been mentioned as an uncommon occurrence, and the presence of a warm spring in the vicinity is suspected.

FIG. 6.—HEAD OF BONANZA CREEK, FROM THE DIVIDING RANGE.

Claims are either worked opencast or by shafts and drifts.

It has been found when the moss is cleared from the surface and water is allowed to run over it, that the frozen ground is quickly cut away under the wearing and thawing action of the water. This method proved so successful in 1899 that a large number of claims are remaining unworked this winter, in order that ground-sluicing during the coming summer may take the place of the drifting or blocking out which had hitherto been carried on during the winter months.

The mode of working during the winter heretofore has proved very costly in all cases, and it did not permit of gravel averaging less than 1½d. to 2½d. (3 to 5 cents according to conditions) per pan being handled. The general method of procedure is to build and light fires against that part of the gravel required to be thawed. A foot or 18 inches ahead would be about as much as one fire would thaw, should it burn well; it would take from 10 to 14 hours to do this properly and the expense of getting the necessary firewood proved to be one of the chief items of expenditure.

FIG 7.—VIEW, LOOKING FROM THE DOME (DIVIDING RANGE), OVER THE HEAD OF HUNKER CREEK: THE ROCKY MOUNTAINS ARE SEEN IN THE DISTANCE.

The bulk of work effected this winter, however, has been done with the aid of thawing-machines, which have proved very economical for winter working. The contrivance is simple enough, and consists of a small boiler (of a capacity according to requirements) from which pipes carry the steam to the working-face. There may be several branches to the pipe at its end, in order to have several points thawing at one face at the same time. A nozzle is shaped at the end by being beaten until the pipe is almost closed, and it is then shorn into a semi-circle in order that it may produce

a fan-shaped jet of steam. The pipe is made flexible in parts, so as to allow of freedom in use. When the steam is turned on, unless the ground is very full of large boulders, the nozzle can be introduced into the gravel at about the same speed that one would push a stick into very stiff clay, and it is left steaming ahead in the gravel for 2 or 3 feet for the space of 2 hours or so: all escapes of steam being prevented by careful caulking with clay, so that the heat is maintained among the thawing gravel. By this means, the heat is concentrated, and will thaw the ground for many feet

FIG. 8.—SLUICING ON THE VICTORIA CREEK, A TRIBUTARY OF THE UPPER BONANZA CREEK.

on each side of the nozzle. The steam-jet has the advantage, besides being cheaper and more effective, of leaving a purer atmosphere behind than that produced by wood-fires. A steam-hoist is the usual accompaniment of the thawing apparatus, and takes the place of the windlass-haulage used during last winter, so that another expensive item has been reduced.

The deposit of gold in the valleys can scarcely be touched upon in this paper, as it implies the description of occurrences as they may exist over nearly 150 miles of creek-claims, which would require special study and preparation to thoroughly detail and the

result would fill a fair-sized volume. For the present, one may say that there are the usual rich pockets and barren places adjoining, which, to the claim-owner, are simply unaccountable; the rough jagged bed-rock proves here, as elsewhere, much better to bottom the shaft on for good pay-dirt than smooth and soapy bed-rock; and the pay-streak has its usual trick of disappearing where most confidently expected and appearing at other times as a surprise to the locator.

FIG. 9.—VIEW OF BONANZA CREEK, OVERLOOKING DISCOVERY CLAIM, FROM THE NORTH END OF GOLD HILL. THE WORKINGS ON THE HILLSIDE IN THE FOREGROUND ARE THE DUMPS OF BENCH AND HILL-SIDE CLAIMS ON ADAMS HILL.

The most distinguishing feature which, as far as the writer's knowledge extends, has not been rivalled in any other placer gold-field to such a great and rich extent, is the wealth of gold that had been discovered in the gravels on the benches and hill-sides of the creeks. Although all the other creeks more or less appear, from prospects obtained, to have the same occurrence, the Bonanza creek has had its hill-sides more thoroughly explored than any other creek. The result shows a long even line of dumps, up to a height of about 500 feet above the present creek level (more especially on the south-western bank), each line of dump pursuing almost the same level and extending for miles of

the creek's length. The line of the workings are unbroken save where some side-stream has forced its way down and carried with it the old deposits from the higher levels, and thereby enriched the lower lying creek-claim. Such an occurrence may be seen noticeably surrounding the Discovery claim on Bonanza creek, where the line of gravel ranging between Gold Hill and Adams Hill has been washed down by the Big and Little Skookum creeks, and has enriched the claims laying in the low level of the valley at that point to a much greater degree than has been discovered for some distance above or below this area.

FIG. 10.—NO. 2 CLAIM, ABOVE THE DISCOVERY CLAIM ON BONANZA CREEK.

The gravel-deposits on the hill-sides indicate that the creeks in bygone times have followed that course, and that upheavals and pressure have so changed the surface of the country that the creeks are now following a lower level than formerly. This change has been assisted by the immense volumes of water which have, at various periods, inundated the valleys and have had a material effect in wearing them down to their present level.

Most of the miners have an inclination for the glacial theory as

accounting for the formation of these deposits, and love to dwell on it when the occasion arises in conversation; but the writer failed to see any actual proof of local glacial action in the cases of the creeks described in this paper, either (1) in the appearance of the gravel, which is distinctly rounded and waterworn and contains only the rock that is peculiar to the vicinity without any admixture of foreign material, or (2) in any trace of striæ or smoothed rock-surfaces.

FIG. 11.—DUMPS ON THE UPPER BONANZA CREEK IN MID-WINTER.

In spite of the Government returns, recording the amount of royalty paid, it is hard to say what the output has been. The policy of exacting a royalty of 10 per cent. on the gross output above £500 ($2,500), an exemption which has now been raised to £1,000 ($5,000) is considered to be a bitter injustice by the community, and there is no doubt that many claim-owners avoid the payments where possible, so that the Government estimate of the output must be under rather than over the mark. During this season most of the richest claims will be exhausted, and from the present summer work will have to be carried on on a larger scale and with cheaper working methods, so as to operate profitably on

the lower-grade gravels, consequently it is hopefully expected on all sides that the Government will see the necessity of substantially reducing the royalty to meet the case.

Outside of the locality that has been merely touched upon in the foregoing remarks, the Yukon territory covers a country which bears the promise of vast mineral wealth of every description—about which little or nothing is known as yet. Rich copper-ore has been discovered close to White Horse Rapids. Coal locally obtained is used already at various points on the Yukon river to

FIG. 12.—VIEW OF CLAIM ON HUNKER CREEK.

supply the shipping traffic, and quartz-reefs in plenty are known to exist in the Teslin and Pelly river valleys.

Outside of the immediate Klondike mining-division, gold can be found almost anywhere on the banks of the Yukon river or its main tributaries in low-grade quantities, and it is commonly known in that northern country that it is hard to pan a dish of gravel where a few fine colours of gold are not obtainable. Engineers who have investigated the extensive auriferous gravel-bodies that line the course of those northern rivers will keenly appreciate

any decisive proof of the actual success of hydraulicing, which will be experimentally tried in the near future.

The climate, the shortness of the sluicing season and the costs of operation are difficulties which, when overcome, will prove the

FIG. 13.—MACHINE FOR THAWING GRAVEL.

immediate interest of the country to be coupled with hydraulic working, for certainly the scope and the material for such treatment is found there in ample abundance.

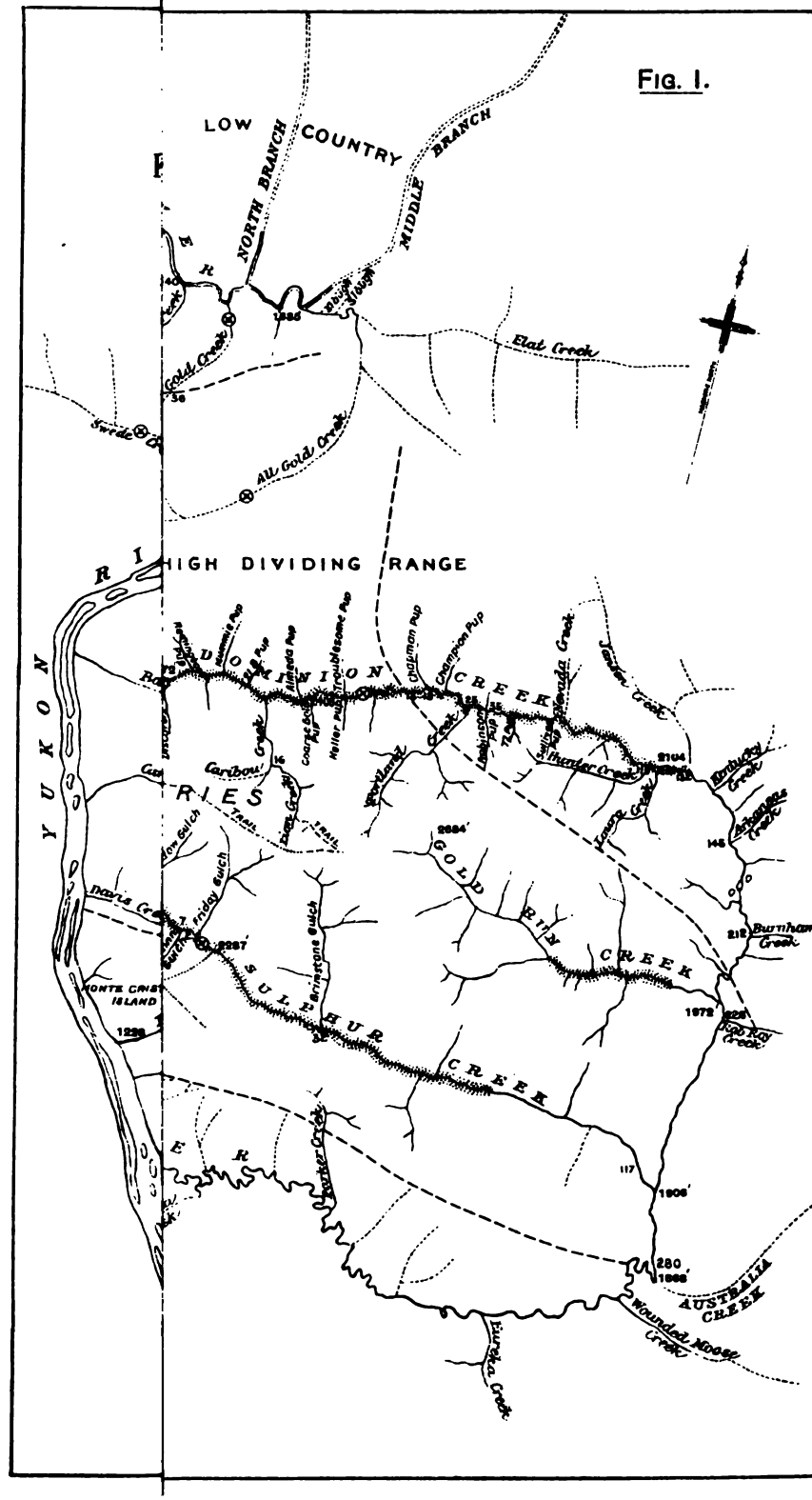
The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. Meiklejohn for his interesting paper.

Mr. A. L. STEAVENSON seconded the motion, which was cordially approved.

Mr. J. MALCOLM MACLAREN's paper on "The Geology of the Coromandel Gold-fields, New Zealand," was read as follows:—

...ike Gold-fields."

FIG. 1.



THE GEOLOGY OF THE COROMANDEL GOLD-FIELDS, NEW ZEALAND.

By J. MALCOLM MACLAREN, B.Sc.

The Coromandel gold-field is situated on the Cape Colville Peninsula, which lies on the eastern coast of the North Island of New Zealand. From its position, it gains advantages equalled by few of the world's gold-fields. It is subjected to extremes neither of heat nor of cold; water is abundant; access is easy, the gold-field lying on the shores of a landlocked harbour, within 4 hours' steam of one of the great traffic routes of the world (Fig. 4).

Fig. 4.—View of Coromandel Township and Harbour, looking westward from the Tokatea Saddle. ×× at the sides of the view indicate the Outcrop of the Main Tokatea Reef.

The first gold in Coromandel, and also in New Zealand—Coromandel being the oldest gold-field of the colony—was found in 1852. At that time, the attention of the diggers, who flocked to the field, was entirely devoted to the alluvial deposits; but, in 1862 the outcrop of the phenomenally rich Scotty's reef was discovered, and since that date Coromandel has been essentially a reefing field, experiencing the usual fluctuations incident to the fortunes of a mining-camp.

The problem of the geological relations of the auriferous series has been dealt with by several observers, but always more or less cursorily. On examining Table I., summarizing the various formations of the gold-fields, it will be seen that the auriferous areas occur in country-rocks differing widely in geological age.

In Table I., the writer has included the Lower Eocene sedimentary beds at Cabbage Bay, which though lying outside the Coromandel gold-field, are yet essential to the correct interpretation of the homotaxial relations of the Tertiary deposits.

TABLE I.—GEOLOGICAL FORMATIONS FOUND IN THE COROMANDEL GOLD-FIELDS.

Formation.	Characteristic Rocks.
6. Carboniferous ... (Maitai Slates of Dr. Von Hochstetter).	Black slaty shales, greywackes, coarse sandstones, crushed breccias, auriferous felsitic rocks of the Tokatea.
5. Lower Eocene (Cretaceo - Tertiary of the Geological Survey Department).	Clay-marls with small coal-seams, slaty conglomerates and foraminiferal limestones.
4. Upper Eocene or Oligocene.	Auriferous andesitic (hornblende-and-augite) lavas, fresh and decomposed tuffs.
3. Miocene	Trachytic and andesitic agglomerates breccias and dykes.
2. Pleistocene	River-terraces and lacustrine beds.
1. Recent	Alluvial-flats, harbour-muds, &c.

Carboniferous (Maitai) Series.—The Maitai rocks, so far as is yet known, form the basement-rock of Cape Colville Peninsula. They are the Maitai Slates of Dr. Von Hochstetter, and one of the most important groups in the New Zealand sequence, giving rise to the chief orographical features in the North Island, and playing no inconsiderable part in the mountain-structure of the South Island. In the former region, they consist of fine-grained argillaceous slates, but on the west coast of the South Island, they pass conformably downwards into a fossiliferous limestone, the nature of the contained fossils sufficiently indicating the geological age of the beds. The most important fossil forms are *Productus brachythærus*, *Spirifer glaber*, *Spirifer bisulcatus*, *Cyathocrinus* and *Cyathophyllum*. At Reefton, also on the west coast, the slates overlying the limestone contain auriferous reefs which have been worked with very satisfactory results.

So far, no fossils have been discovered in the slaty shales of the Peninsula, or indeed of the North Island, if we except certain indistinct markings which may be fucoidal. In the Coromandel district, the Carboniferous rocks consist of fine-grained dark- and light-coloured greywackes, black slaty shales, and coarse sandstones, together with flows of an ancient volcanic rock, which, from its felsitic nature and from the preponderance of soda in its alkalies, the writer concluded to be a keratophyre.

The geological sketch-map (Fig. 1, Plate XVII.) shews that the slaty shales are mainly exposed along the western flank of the main dividing range, varying from 1,000 to 1,900 feet in height. In the Tokatea area, however, the Palæozoic rocks are represented on the eastern side of the range by black slaty shales and felsitic lavas, as shown in Fig. 2 (Plate XVII.). This area is unique, because the auriferous reefs are developed in felsitic lavas; while throughout the remainder of the Cape Colville Peninsula, the auriferous lodes traverse andesitic lavas of Tertiary age. Together with the felsitic lavas and tuffs, occur dyke-like masses of quartz-porphyry containing bipyramidal phenocrysts of quartz. The felsites are contained apparently between two parallel ridges of black slaty shales, whether interbedded or merely occupying a depression, is not at all clear. Hand-specimens of this felsite shew it to be a compact dull grey rock, translucent on thin edges and breaking with a subconchoidal fracture. In thin sections under the microscope, the base is felsitic, consisting of a cryptocrystalline aggregate of quartz and felspar—the result of devitrification. The felspar shews abundant polysynthetic twinning and the extinction-angle, 14 degrees, indicates the existence of acid felspar. The following is an analysis of this rock:—

Silica, SiO_2	59·35
Alumina, Al_2O_3	21·30
Ferrous oxide, FeO	10·06
Lime, CaO	1·58
Magnesia, MgO	0·48
Potassium oxide, K_2O	0·34
Sodium oxide, Na_2O	7·68
	100·79

The presence of a soda-lime felspar, together with the preponderance of soda as shown by analysis will therefore bring this rock into the group of keratophyres. These Tokatea rocks have hitherto been grouped with the Upper Eocene auriferous andesites.

On the western flank of the main range, black slaty shales are exposed at an elevation above sea-level of 1,000 feet. The best section of these rocks is found along the course of the Tiki creek, where the strata for a distance of 1½ miles strike east-north-east and west-south-west and dip east-south-eastward at high angles, giving, therefore, a thickness in this section of not less than 5,000 feet. Here also, interbedded with the slaty shales, is a felsitic rock resembling in every respect that of the Tokatea district. At the Matawai falls, farther south, the Palæozoic rocks are composed of false-bedded sandstones overlying a soft shaly band.

A microscopic examination of the black slaty shales and sandstones from the southern portion of the Coromandel area throws some light on the origin of these rocks. They are composed of fine-grained rounded and subangular fragments, cemented by a siliceous base. Many of the fragments are evidently derived from an ancient rhyolitic area—probably from that which also furnished the felsitic flows of the Tokatea and of the Tiki. The latter fragments vary from 0·05 to 0·10 inch in diameter and shew fluxion-structure as clearly defined as in many modern rhyolites. The lath-shaped felspars are oriented, and on encountering an allogenic phenocryst curve round it, resuming their parallelism on the farther side.

With the exception of the gold of the Tokatea area, the minerals of the Palæozoic rocks are in no case of economic importance.

Lower Eocene.—Strata of Eocene age, though not exposed in the Coromandel area, are found a few miles to the north and furnish important evidence of the age of the auriferous andesites of the Peninsula, in fact, almost the only evidence procurable. At the same time, however, the evidence is mainly negative, but it is of its kind conclusive. One of the members of the sequence is a coarse conglomerate, containing not a trace of any volcanic rock, being entirely composed of rounded slate-boulders and pebbles. At the present time, the conglomerate-area is enwrapped by andesite-flows, so that had it been of subsequent date to the volcanic outbursts, it must have contained internal evidence to that effect. A dense forest prevents the relations of the sedimentary to the volcanic rocks from being determined by superposition.*

*Mr. A. McKay, Government Geologist, has informed the author, since this paper was written, that he has discovered, at Cabbage Bay, a section in which the volcanic rocks directly overlie the sedimentary deposits.

The Lower Tertiary formation consists of estuarine marls, slaty conglomerates, marine limestones and marls, the latter containing thin seams of coal. The calcareous sandstones and limestones contain, among other fossils, *Turritella gigantea*, *Fusus* sp., *Natica solida*, *Scalaria Brownii*, *Cucullæa* sp., *Ostrea Wullerstorfi*, *Pentacrinus stellatus*, *Hemipatagus tuberculatus* and teeth of *Lamna Huttoni*. In the estuarine marls are preserved plant-remains of *Blechnum priscum*, Ettingshausen (*Alethopteris* of Hector?), *Flabellaria sublongirachis*, Ettingshausen, *Bambusites australis*, Ettingshausen, *Fagus* sp. This flora would assign to the strata a position equivalent to that of the Pakawau Beds, that is, at the base of the Cretaceo-Tertiary.

Upper Eocene Volcanic Rocks.—This volcanic series is the most important in the Peninsula, and contains the principal auriferous reefs. It consists of andesitic lavas, tuffs and breccias, for the most part decomposed, but in places solid and unaltered. Dykes of this age are absent or, at any rate, have not been recognized—the "dykes" of the miners consisting merely of zones of unaltered and unweathered lavas. When freshly exposed, the andesites are dark- in places, almost black—and contain no porphyritic constituents. Rarely the andesite is dark-grey, owing its light coloration to the predominance of porphyritic plagioclase-felspar. The lighter rock weathers to a light-grey or greenish-grey incoherent mass—the "sandstone" of the miner—and the darker to a brownish-red or brownish-yellow clay.

Vesicular structure and consequent amygdaloids are entirely absent in the lavas, whose whole facies indicates a flow emanating rather from a fissure than from separate vents. The few tuffs and breccias found result, the writer is inclined to think, from parasitic cones on the lava-flow and not from the main fissure-vent.

Mr. A. McKay, Government Geologist, has divided the auriferous lavas into an upper and lower series.* The weight of evidence, however, appears to the writer to be opposed to this division, and he has accordingly considered all the lavas to be members of one group.

The auriferous andesites (andesites containing auriferous reefs)

* *Paper and Reports relating to Minerals and Mining, New Zealand*, 1898, "Report on the Geology of the Cape Colville Peninsula," C. 9.

occupy the greater portion of the area under discussion. In the north-west, about ½ mile west of the Kapanga shaft, they consist of great flows of a dark-grey pyroxene-andesite forming bluffs 400 to 500 feet high. The rocks of the Kapanga and Scotty mines are fine-grained tuffs, interstratified with solid flows of a dark hornblende-andesite. The tuffs and lavas dip south-west and south at low angles, disappearing under the Miocene tuffs of the Blagrove Freehold mine. Through the older tuffs and lavas, the Kapanga shaft has been sunk to a depth of 1,000 feet, and from the bottom of the shaft a bore-hole penetrated a further 150 feet, making a total depth of 1,150 feet. The last 500 to 600 feet was sunk entirely through tuffs.

From the Kapanga area, the andesites rise to a height of nearly 2,000 feet on the Success Range, the New Hauraki Gold Properties' workings being in this rock. From this mine, to the east and north-east, there is a great development of volcanic rock overlying the felsitic area of the Tokatea and extending eastward as far as the Four-in-Hand mine on the Waikoromiko creek.

The main northern mass of andesite sends out several tongues running south-westward and southward. Of these, the westernmost runs through Dacres Hill and through the Hauraki area to Keevin's Point. At Paraparakino, on the coast, the andesites are weathered by the removal of the interstitial matter, thus leaving each felspar isolated on its little pedicel of rock and glistening in the sun like a scale of mica.

The major portion of the Hauraki area is composed of a highly decomposed andesite. The ferro-magnesian silicate is probably augite, but its nature is a matter of some doubt owing to the difficulty of procuring a fresh sample. A central core of only partly decomposed rock appears to run from the Hauraki South shaft northward through the Golden Pah, Hauraki and Bunkers Hill mines—a course approximately parallel to the direction of the ridge.

An isolated exposure of the auriferous series is found in the Preeces Point Peninsula, which rises slowly from the alluvial flat and with an elevation of 200 feet runs westward for nearly 2 miles (Fig. 3, Plate XVII.). The andesites are well decomposed, and are identical in appearance with those of the Hauraki area, of which Preeces Peninsula may be regarded as a southerly outlier.

In the southern portion of the Coromandel district, the andesites are well developed, but are of economic importance only in three

gold-fields of small extent and of little importance, namely, the Tiki, Pukewhau and Matawai. There are small quartz-leaders which have from time to time yielded rich pockets of gold-ore.

Miocene Breccias and Lavas.—These beds unconformably overlie the auriferous andesites and differ widely from them in petrological and lithological characters. While the auriferous series is built up, in the main, of lavas of a somewhat basic type, the overlying Miocene beds are composed of a great agglomeration of coarse trachytic or highly acidic andesite-rocks. With the exception of the Castle Rock dyke, they are disposed only round Coromandel Harbour and along the sea-coast, increasing in thickness to the south. In many places, notably at the entrance to Coromandel Harbour, the breccias and tuffs are rudely stratified.

They are well developed around Kitahi Bay and from this Miocene centre of eruption, a fissure-line may be traced in a south-easterly direction, at first giving rise to the fine-grained tuffs (which probably overlie the auriferous series) seen in the Blagrove Freehold, Kathleen Crown and Kathleen mines. But with increasing distance from the point of eruption, the volcanic energy sufficed to fill the fissure only, forming a dyke which, owing to the agents of denudation, now constitutes a prominent feature in the landscape. In its course it forms Castle Rock or Motutere, a remarkable castellated crag, 1,724 feet above sea-level. Beyond Castle Rock, the dyke is traced for a considerable distance, its total length being certainly less than 9 and probably as much as 14 miles.

The tuffs of the Kathleen area are light in colour, containing occasional large boulders or fragments. Quartz-reefs in this particular rock, though well defined and well mineralized, have not, so far, yielded payable results.

Pleistocene and Recent Beds.—These are well developed at the debouchment of the various streams, forming river-terraces and river-flats. Throughout the alluvium, quartz, containing gold, is scattered; and in places, notably at the mouth of the Kapanga creek, in apparently payable quantities. The gold, however, is still contained in the quartz and it is therefore impossible to effect cheap mechanical separation. As a matter of fact, the gravel has not travelled sufficiently far to secure the thorough disintegration of the particles and the consequent liberation of the gold.

Corresponding with the high-level gravels and like them, shading insensibly into the overlying recent alluvium, are lacustrine beds which probably underlie a considerable area of recent drift. These have been exposed in one place only—in the Kathleen shaft—and consist of blue and yellow muds containing a fairly well preserved *Unio*—probably *Unio menziesii* (Grey). The average depth of the alluvium over the flat varies from 200 to 300 feet.

Reefs and Reef-systems.—The reefs of the Coromandel gold-fields are as erratic in course, dip and gold-content as those of any gold-field in the world. No general conclusion can be deduced from an inspection of the dips and strikes, and no comparisons can be made to determine when a reef may or may not contain gold. Two reefs may be parallel and in close proximity, yet the one may be absolutely barren and the other highly auriferous. The proximity or otherwise of the Palæozoic slaty shales does not appear to modify the auriferous character of the reefs, for while the Tokatea reefs occur in Palæozoic rocks, the equally rich Kapanga, Scotty and Hauraki reefs are certainly hundreds and perhaps thousands of feet above them. Further, while some reefs, as the Tokatea, contain most gold when almost vertical, others, as the Scotty, are richest when approximating to horizontality.

As a general rule, the richest reefs occur in belts of soft decomposed andesite and are, again speaking broadly, the smallest, the best returns having been obtained from reefs 4 to 12 inches wide, and in no case have the large reefs, 20 to 30 feet wide, yielded payable results.

The reefs of the Coromandel gold-field may be divided into six systems: the Tokatea, Kapanga, Hauraki, Preeces Point, Pukewhau and Matawai; and the first-mentioned three alone are of importance.

The Tokatea system embraces the reefs worked along the crest of the Tokatea Range as far south as the Success section of the New Hauraki Gold Properties. The striking feature of this system is the main or big Tokatea reef—a quartz-lode, varying from 30 to 150 feet in width, striking north-and-south, and dipping westward at angles of 50 to 55 degrees. It forms a salient feature in the landscape, standing out in places as a white wall and covering the slopes below with boulders of white quartz (Fig. 5). Several trials of the lode have been made, but as the results have

shown a bullion-content of only 1 to 2 pennyweights per ton, these have led to no practical results. Cross-reefs join the main reef from both the hanging-wall and foot-wall sides, but it is only on the foot-wall that these have yielded good returns. Of the foot-wall cross-reefs, the most important are the Tokatea lode, the No. 1 or Tribute lode of the Royal Oak mine, and the Rainbow reef of the Hauraki Associated mine. These three reefs have yielded rich gold continuously for the last 30 years.

In the Kapanga area, the principal reefs are the Scotty and Kapanga, the former the pioneer reef of the gold-field, having

FIG. 5.—VIEW OF THE TOKATEA SADDLE, SHOWING MINE-WORKINGS ON THE FOOT-WALL OF THE MAIN TOKATEA REEF.

been discovered in 1862, when its outcrop yielded many thousand ounces to the lucky prospectors. Both reefs dip north-westward at very low angles, in places becoming almost horizontal.

The Hauraki system is grouped round the mine of that name. The two principal reefs are the No. 2 Hauraki (Legges) and the Green Harp. The former (only 6 to 12 inches wide) has during the past 4 years yielded bullion worth about £300,000. The Green Harp reef, to which a somewhat romantic incident is attached, in one year returned to the shareholders more than £40,000. On following this reef of late years, its strike has gradually changed, until it now pursues a northerly course at right angles to its original east-and-west strike.

An inspection of the map (Fig. 1, Plate XVII.) shews that the great majority of the reefs, and all the richest areas, are included in a belt of auriferous country about 2 miles wide, extending north-eastward from the Hauraki and Preeces Point areas to the Tokatea and Success mines respectively; and probably 95 per cent. of the gold-output of the Coromandel gold-field has come from within this belt.

Nature, Associates and Value of Electrum.—The "gold" of the miners is an electrum containing on an average about 75 per cent. of gold and 25 per cent. of silver. In the Hauraki and Kapanga

FIG. 6.—VIEW OF THE HAURAKI AURIFEROUS AREA, WITH THE KATHLEEN MINE (IN THE CENTRE), AND THE HAURAKI MINE (A LITTLE TO THE RIGHT-HAND), WITH COROMANDEL HARBOUR IN THE DISTANCE.

districts, crystallized gold is absent, but in the Tokatea area, and more especially along the crest of the range, it is the rule rather than the exception. The crystals are generally very imperfect indeed, showing only a single edge or face. Occasionally, however, more perfect specimens have been obtained, the finest of which contain well developed faces of the cube, the octahedron and the rhombic dodecahedron, as already described by the author.*

Gold is common in a calcite-matrix (impure Iceland spar) in both the Kapanga and Tokatea districts. It is scattered promis-

* *Transactions and Proceedings of the New Zealand Institute*, 1898, vol. xxxi., page 492.

cuously throughout the calcite, and does not appear to have been deposited with any reference to the cleavage-planes of the latter, which indeed are crossed at all angles. As a general rule, this electrum is poorer in quality than in a quartz-matrix.

Native arsenic is, in the Coromandel district, an almost infallible "indicator" of gold. The hollow centre of the typical native-arsenic geode is generally filled with fine dendritic threads —dichotomously branched—of the precious metal, and more rarely scales and plates are found between the concentric spheres of growth of the geode. Other associates of the "gold" are antimonite and mispickel. In the Kapanga mine, it has been observed that a green discoloration of the country-rock often precedes the discovery of rich quartz—a colour due probably to melanterite or iron sulphate.

The auriferous quartz occurs in the reefs in chutes, which are variable in width, breadth, and depth. In the Hauraki No. 2 reef, the chute was 150 feet wide and dipped north-eastward. The variability of the chutes will be readily understood when it is remembered that they represent the open-water channels through the reef at the time when the gold was being deposited. Experience has also shown that the richest points in a reef are found at the intersection of cross-reefs, the main reef probably supplying the auriferous solution and the cross-reefs the precipitant.

TABLE II.—AVERAGE VALUES PER OUNCE OF ELECTRUM IN EACH MINING DISTRICT.

Name of District.	Value per Ounce.
Hauraki, Eastern side	£2 18 0
Do. Western side	3 1 6
Kapanga	2 17 6
Matawai	2 13 0
Pukewhau	2 16 0
Success	2 19 6
Tokatea	2 14 0

The value of the electrum or gold varies in different localities from £2 9s. 6d. to £3 5s. per ounce; but it is fairly constant for any given locality. Table II. shews the average value for each district. From Table II. it will be seen that the bullion becomes poorer in quality as the reefs approach the Palæozoic slates. A decrease in value with increased depth is also observed. In both these cases, however, the greater proportion of silver must be ascribed to less exposure of the ore to solvent agents.

Mining and Metallurgical Practice.—Owing to the fact that the payable reefs are small, and that 99 per cent. of the bullion comes from "specimen-quartz" containing often 6 ounces of gold per pound of quartz, the necessity for extensive pit-gear is obviated, nor, in fact, is there anything of importance to note with regard to mining practice. The mines are drained throughout by Cornish pumps. Motive power is furnished by coal, which is cheap and abundant.

The ore being perfectly free-milling, the simplest amalgamation processes are competent to save 95 to 99 per cent. of the bullion-content. The milling methods of 30 years ago are therefore still followed on the gold-field, and are amply adequate for their purpose.

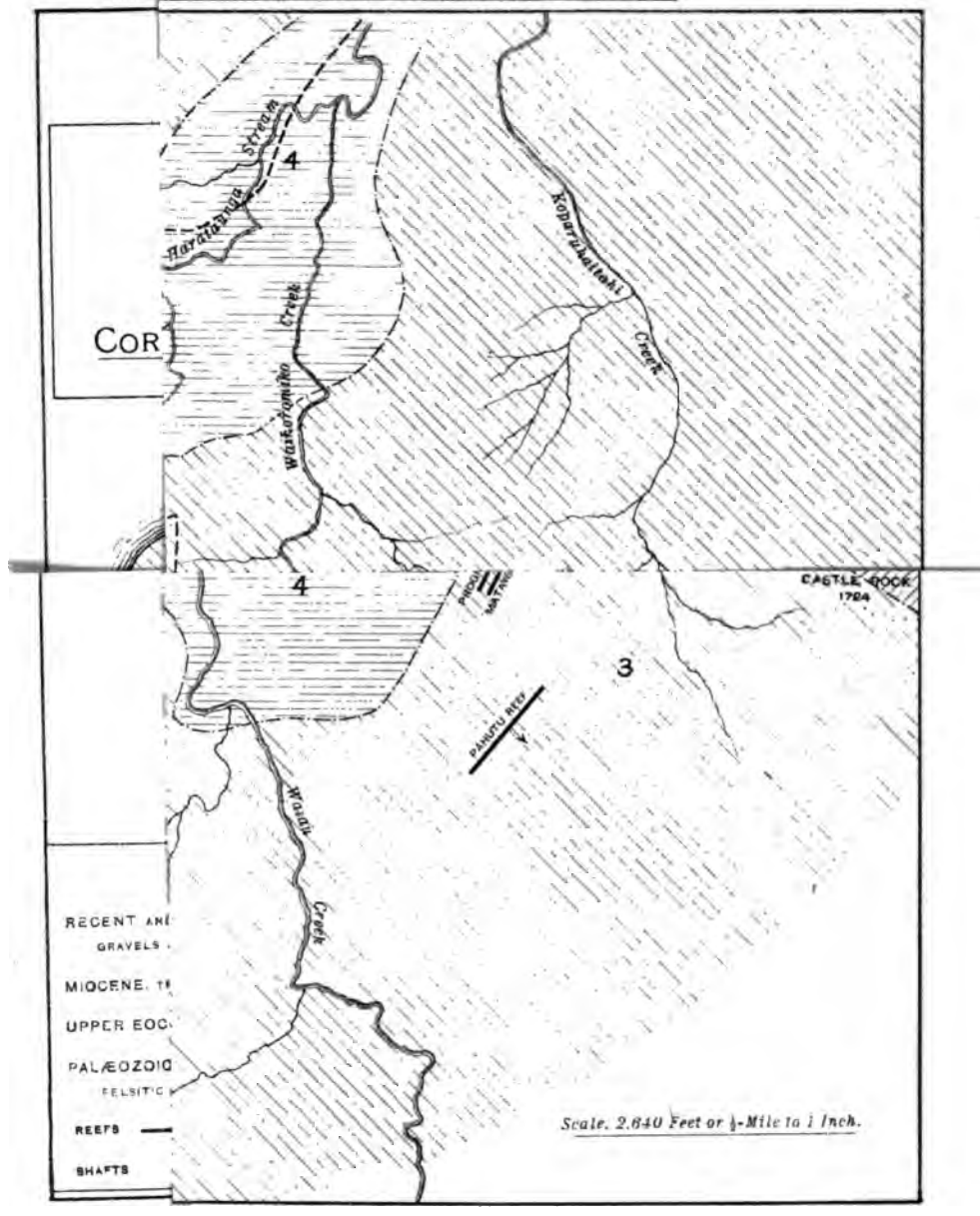
Conclusion.—In conclusion, the writer is of opinion that though the Coromandel gold-field will probably never give employment to a large number of workmen, and though it can hope for nothing from improved metallurgical processes, for it possesses, speaking broadly, no low-grade auriferous reefs, yet the reefs, judging by past experience, are by no means exhausted, and will yet afford further *bonanzas* like those of the Hauraki and Royal Oak mines, the discovery of which precipitated a memorable boom in New Zealand gold-mines.

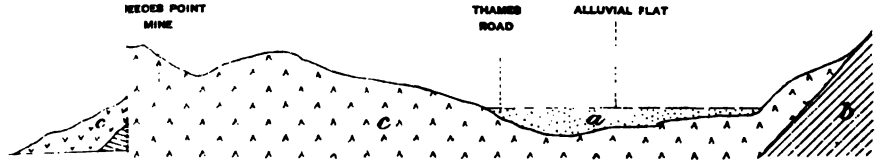
The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. MacLaren for his valuable paper.

Mr. C. C. LEACH seconded the motion, which was cordially approved.

Mr. JOSEPH HASSALL's paper on "Mining in the Southern Klerksdorp Gold-fields, Western Transvaal," was read as follows:—

...romandel Gold-fields, New Zealand."





'ION FROM PREECES POINT TO THE MAIN RANGE.

a RECENT ALLUVIUM. *b* PALÆOZOIC SLATES. *c* AURIFEROUS ANDESITES.

MINING IN THE SOUTHERN KLERKSDORP GOLD-FIELDS, WESTERN TRANSVAAL.

By JOSEPH HASSALL.

Introduction.

The gold-fields of Klerksdorp, the "Schoonspruit goud-velden," are situated 118 miles by rail south-west of Johannesburg.

The southern portion (which will be described in this paper) is bounded on the north by the township of Klerksdorp, on the south by the southern boundary of the mine-claims of the Eastleigh Deep, Limited, on the east by the Commonage mine-claims of the Klerksdorp Proprietary Mines, Limited, and on the west by the mining-leases of the Eastleigh Mines, Limited, and the Roodepoort farm. The area covered is about 20 square miles, being part of the Klerksdorp town-lands, and the Nooitgedacht and Roodepoort farms (Fig. 1, Plate XVIII.).

The country is slightly undulating, and covered with trees and bushes.

The mines that have been worked comprise the Eastleigh mines of the Eastleigh Mines, Limited; the Gold Estate mine of the Klerksdorp Gold and Diamond Company, Limited; and the Niekerk mine of Niekerk, Limited. The first and second mines have been gold-producers, and the third is still in a developing stage. In addition, the Eastleigh Deep, Limited, the Southleigh Mines, Limited, and other companies have done a certain amount of work on the Klerksdorp Black Reef, Gold Estates Reef and Niekerk Reef formations; and prospecting to some extent has been carried on over the remaining area.

The mines are all worked with the main object of winning gold, though platinum with iridium and osmium are found in the ore of the Eastleigh mine, and the discovery of diamonds has been reported from the Gold Estates mine.

Geology.

Geological and stratigraphical theorists have ventured to state that the Klerksdorp formation is a continuation of that of the Witwatersrand, and in some cases have even correlated the conglomerate-reefs there mined with the Black, Elsburg, Leigh and Bird reefs, and Main Reef Series of the Witwatersrand gold-field. But beyond the fact that the Klerksdorp Black Reef (mined by the Eastleigh Mines, Limited) occurs under conditions similar to those of the Black Reef south of Johannesburg, there appears to be at present no proof of such contentions, and all attempts to class the other conglomerate-reefs of Klerksdorp with those of the various series of the Witwatersrand must be considered as hypothetical. For instance, in a cross-section (Fig. 2, Plate XVIII.) of the country as disclosed from surface and mining developments, for 4 miles to the south of the township of Klerksdorp, the strata, taken as a whole, are not similar to anything yet discovered over a like distance along the Witwatersrand formation, from Krugersdorp, through Johannesburg, to Boksburg.

In Klerksdorp, and its near vicinity, there is a shallow alluvial deposit, overlying an overflow of igneous rock, the depth of which in the township has, up to date, not been ascertained. South-east from this point for about 15,000 feet, altered sandstones (quartzites), carbonaceous shales and conglomerates, with occasional overflows of igneous rock and dyke-intrusions, occur; and southward again is an extensive series of compact limestones, extending from the claims of the Eastleigh Mines, Limited, and Eastleigh Deep, Limited, to about 6 miles beyond, where the Coal-measures of the Orange River Colony are found.

The altered sandstones are recognizable and easily traceable on the Bush Rand or Black Reef ridge, the Gold Estates ridge, and also, though in a less degree from the Commonage mine-claims through the Little Mynpacht and the Niekerk mine-claims, into the Roodepoort farm (Fig. 1, Plate XVIII.).

The general trend of the formation is north-easterly and south-westerly, dipping both to the north-west and south-east at angles varying from 8 degrees to nearly vertical. This peculiarity of dip may be accounted for by the wave-like shape of the country, which forms a series of troughs and ridges; and

at the crests, where the country-rocks have been denuded, the outcrops are visible, and the strata frequently dip in both directions. The excavations of the early prospectors, at various distances apart upon the same line of reef, have been so inconsistently made as to give rise to the belief that their original impression must have been that two parallel veins were being followed, dipping at opposite angles, instead of exploring the denuded ridge of one formation. The occurrence of the outcrops, usually found on the crests of the ridges, in some measure explains the fact of the gold-values improving in depth, as the ore in the trough-depressions is as a rule found to be of a higher grade, and the reef of greater width than on the tops of the ridges.

Water.

The Vaal river is distant from 4 to 7 miles south of the mines, and the Schoon spruit from 1¼ to 3 miles north-west, and at no point does the elevation exceed 200 feet above water-level. The underflow, however, is very strong, and the mine-water on most of the properties probably will be found nearly sufficient for all needs, if the effect of its acidity can be destroyed.

Fuel.

The collieries in the Orange River Colony, three in number, and distant from 10 to 14 miles, can deliver coal of a fair steam quality by waggon-transport to the mines at 20s. to 25s. per ton. Firewood is scarce, and the average price is £2 per waggon-load of bush timber.

Transport.

The Klerksdorp Station of the Netherlands Railway is from 2 to 5 miles from the mines. The railway-rate has been 9s. 10d. per 100 pounds for heavy machinery from East London, in Cape Colony.

Labour.

The mines have been worked by European, American, Colonial, and native miners. The Transvaal Boer takes but little interest in mining. In respect to the natives, East Coast "boys" are considered to make the best underground workmen; Zulus, Basutos, and Cape natives make fair battery and general

surface workmen. There is little distinction between the labour in this district and on the Witwatersrand, as distance is no object to natives when seeking employment.

The following lists record the rates of wages paid to European and native workmen. The wages of European workmen are similar to those prevalent in Johannesburg, while the wages paid to natives appear to be slightly higher, but this is in reality only apparent, as the cost of the expensive agency system in vogue on the Witwatersrand, if added to the rates paid, would in many cases make the wages of natives equal to, if not higher than at Klerksdorp.

WAGES OF EUROPEAN WORKMEN.

	Per Month. £	s.		Per Month £	s.
Miners, wet mines ...	25	0	Storekeepers	20	0
,, dry mines ...	22	10	Compound-manager ...	22	10
Engine-drivers ...	22	10	Amalgamators	25	0
Fitters	25	0	Cyanide hands	22	10
Blacksmiths	22	10	Clerks	20	0

WAGES OF NATIVE WORKMEN.

	Per Day. s.	d.		Per Day. s.	d.
Hammer-boys	2	3	Tank-boys	2	0
Shovel-boys	1	9	Tramming residues... ...	2	0
Tram-boys	1	9	Fitter-boys	2	3
Shaft-boys, dry	2	6	Blacksmith-boys (strikers)	3	0
,, wet	3	0	Carpenter-boys	2	0
Station-boys	1	9	Police	3	0
Stokers	2	6	Compound-cooks	2	0
Engine-cleaners	1	9	Surface-labour, general ...	1	9
Headgear-boys	2	0	,, ,, special ...	2	0
Mill-boys	2	0	Zinc-cutters...	2	3
Crusher-boys	2	0	Office-boys and store-boys	3	0
Surface-trammers ...	1	9	Assay-office-boys	2	6
Mule-drivers	2	6	Coal-boys, off-loaders ...	2	6

The following descriptions of mines have been written after personal inspection, and from information and plans kindly supplied by Mr. J. T. Milligan, late manager of the Eastleigh Mines, Limited; Mr. P. O. Wilson, late manager of the Klerksdorp Gold and Diamond Company, Limited; Mr. E. Y. Surtees, late manager of the Eastleigh Deep, Limited, and agent of the Southleigh Mines, Limited; Mr. E. S. Burstow, of the Niekerk, Limited; Messrs. Adams & Twiddy, engineers, of Klerksdorp; and Mr. G. Hurtzig, late secretary of the Klerksdorp Chamber of Mines.

The Eastleigh Mines, Limited.

This company are owners on the Nooitgedacht farm of a mynpacht (or mining lease) of 860 acres, and 443 adjacent and deep-level claims of 665 acres. The company also own 2,447 acres (which, however, do not concern this paper) on the Witkop farm. The mining lease and adjacent claims form one block, with an area of 1,525 acres, bounded on the north by the townlands of Klerksdorp, and on the south by the claims of the Eastleigh Deep, Limited.

The conglomerate-reef mined here is a portion of the Klerksdorp Black Reef, the strike of which is north-east and south-west, with an average dip of 9 degrees to the south-east. The outcrop of the reef is traceable throughout the whole length of the property, a distance on the trend of the formation of about 10,000 feet (Fig. 3, Plate XVIII.). From the outcrop to the south-eastern boundary, there is an average width of 3,500 feet on the dip. The foot-wall of the reef is diabase, and the hanging-wall sandstone (quartzite); in places, arenaceous shales a few inches thick intervene between the conglomerate and the main sandstone hanging-wall; while in others, the reef is cemented directly to the sandstones. The diabase foot-wall forms a series of troughs and ridges, while the sandstone hanging-wall is exceedingly regular and even, the reef being found thicker and of a higher grade in the trough-depressions, and generally thinner and of lower grade on the crest of the ridges.

Two diorite-dykes traverse the mine, practically parallel to each other and 600 feet apart, and at an angle of 55 to 60 degrees to the trend of the formation. The dykes, 5 feet and 10 feet thick respectively, cause a displacement of the reef of some 20 feet, and are located at the eastern end of the mine.

The cemented conglomerate-matrix contains nodular pyrites, segregations of quartz, chert, and quartz- and quartzite-pebbles, which are for the most part rounded, only a few being of angular form. The oxidized zone varies in depth, namely, from 100 feet to 300 feet, measured on the inclination of the reef from the surface. The pay-ore streak can be taken to average 42 inches in thickness, although the reef sometimes thickens to 20 feet between the walls. The pay-streaks can be fairly easily followed, as the chert and coarser quartz-pebbles

are the indicators. The reef has been proved to contain ore-bodies of value at greater or lesser depths by inclined shafts sunk at various distances apart along the line of outcrop.

The south-western section of the mine, the one last worked, covers about a third of the whole area, and the greatest depth reached is 1,043 feet, measured on the incline, or about 180 feet vertically.

The inclined hauling-shafts comprise the Main and No. 1 West shafts, both 10 feet by 6 feet inside timbers, sunk for the most part in the foot-wall to lengths of 1,043 and 790 feet respectively. In addition, there are three other inclined shafts (No. 2, No. 9, and No. 11 East), and eight shafts and other excavations sunk by previous owners and prospectors, and now abandoned.

Five levels have been driven from the Main shaft and three levels from No. 1 West shaft, none of which are as yet worked out, the stope-faces being advanced to the north-east and south-west, and not to the surface. The levels in the Main shaft connect with stopes having 2,565 feet of working-face, and in No. 1 West shaft with stopes having 2,240 feet, the whole of these faces averaging an assay-value of 12 dwts. of gold to the ton of ore.

It has been calculated that from No. 2 East shaft to the south-western boundary of the property, a distance of 2,500 feet, 148,473 tons of payable ore have been proved that could be delivered to the mill at an average assay-value of 10 dwts., allowing for a loss of 2 dwts. per ton in mining and transport from the stopes to the mill. This estimate is upon 39 inches, being the average thickness of the pay-streak, instead of 42 inches that had been previously taken, 25 per cent. being deducted for pinches on the rolls and for poor ore. It is considered that there is ample proof from assay- and battery-tests that this pay-ore streak is sufficiently rich in gold to deliver to the mill, rock yielding on the average 10 dwts. per ton, with the exception of a poor zone from No. 2 East shaft to No. 6 East shaft, or a distance of 2,200 feet. The reef is strong and undisturbed, and has a thickness of 6 feet between excellent walls, with every appearance of continuity on the faces of the Main and No. 1 West shafts, the greatest depths reached in the mine. Against this, it cannot be ignored that, in the deep levels of the

Eastleigh Deep, Limited, the Klerksdorp Black Reef has been proved thin and of little value. Whether this deterioration be local or otherwise, it must be taken into account that at some point not yet ascertained, between the face of the Main shaft of the Eastleigh Mines, Limited, and the No. 2 shaft of the claims of the Eastleigh Deep, Limited, a distance of 2,500 feet, the reef will undoubtedly become thin, and an allowance must therefore be made in estimating the life of the mine. Consequently, if 60 per cent. be deducted for pinches on the rolls and poor ore, instead of 25 per cent., as in estimating the reserve-ore in the ground being mined, and after meeting every likely contingency, the life of the mine, with a heavy mill of 80 stamps, may be taken as of 34 years' duration.

It must not be overlooked, however, that the total width of the property is 5,800 feet, the whole of which is on the dip of the formation, and from the outcrop of the Klerksdorp Black Reef to the south-eastern boundary is an average of but 3,500 feet, leaving therefore 2,300 feet from the north-western boundary to this outcrop for further exploitation. As discoveries have been made on neighbouring claims of gold-bearing conglomerates, whose trend is either in the same direction or that dip into this portion of the Eastleigh mines, there is always the possibility of reefs with payable ore-bodies, other than the one now worked, being discovered and used to augment the future output.

About 40,000 gallons of water can be discharged daily into the service-reservoirs; and 24,000 gallons an hour is pumped by one pump (run 12 hours out of 48 hours) from the Schoon spruit, the station at the spruit being about 7,000 feet from the mine. The acidity of the mine-water is neutralized by mixing with the alkaline water from the spruit.

About 900 tons of coal are consumed per month and delivered at the mine by waggon-transport, from the collieries of the Pilgrims Mining and Estate Company, at Groenfontein (Orange River Colony), distant about 12½ miles.

With the exception of close timbers, 10 feet down from the surface at each inclined shaft, little timber is required throughout the mine. The stopes and shafts, as the ore is worked out, are supported by pillars, and the rail-sleepers are laid without sills.

The ore is delivered from the mine into the headgear-bins at the Main shaft and at No. 1 West shaft, whence it is carried by mechanical haulage to the crusher-house, and thence to the ore-bins at the mill of 60 stamps, where a 400 meshes screen is used and the ordinary copper-plates. The tailings are delivered to 8 potassium-cyanide vats, and by gravitation the cyanide-solution flows to 6 extractor-boxes. Slimes that are considered sufficiently rich in gold are sun-dried, mixed with tailings-residues, and treated in 9 other vats.

The output of gold during 1897 was:—55,091 tons crushed in the mill produced 6,230 ounces; 53,585 tons treated by the cyanide process, 17,256 ounces; and 750 tons by the dry process, 171 ounces.

The Klerksdorp Gold and Diamond Company, Limited.

This company own two mining leases, locally known as the "Large and Little Mynpachts," whose areas are 1,562 acres. The Large Mynpacht on the north is contiguous in part to the southern boundary of the Commonage mine-claims, on the south it is distant about 3,000 feet from the Roodepoort farm, on the east 1,600 feet from the Niekerk claims, and on the west is bounded by the township of Klerksdorp.

The reef worked is the Gold Estates Reef, and the trend of the formation with which it is interbedded continues through the mynpacht for some 11,554 feet, having a south-west to north-east strike, and faulting to the north-west about the centre of the property for a considerable distance.

The Ada May Reef and Commonage Reef, besides two small pebble-reefs, also traverse the estate.

Gold Estates Reef.—There are five inclined shafts sunk from the outcrop, and following the foot-wall of the lode. Nos. 2 and 4 shafts are main winding-shafts, and are timbered to 10 feet down from the surface. The first level is 100 feet down the incline, and 60 feet vertically. All the shafts are connected, and there is a total working-face of 2,000 feet. No faults of consequence have been met with, and the whole face can be stated as being in ore (Fig. 4, Plate XVIII.).

Other levels are being developed north-east and south-west of No. 4 shaft.

Other developments are a ladder-way between Nos. 3 and 4 shafts, down from the surface to the second level, prospecting drives and raises for stoping purposes.

The dip of the reef is to the north-west, and varies from an angle of 12 degrees in No. 3 shaft to an angle of 30 degrees in No. 4 shaft. The hanging-wall and foot-wall both consist of quartzites, and are of such hardness as to render timbering practically unnecessary, pillars of ore being left for support to the stopes, shafts and drives.

The reef is a large-pebble reef, the pebbles on the foot-wall measuring sometimes as much as 6 inches in diameter, but towards the hanging-wall they become much smaller. The matrix of the reef from the first level to the surface is oxidized, though in places patches of blue (pyritic) ore are found intermixed with the oxidized ore in a somewhat unaccountable manner. The ore on the second level being reached, becomes blue and highly pyritic. The thickness of the reef towards the south-west of the mine averages 5 feet; going east it thickens in the vicinity of No. 4 shaft from 10 feet to 20 feet; and thence to the north-eastern working-faces of the mine it thins to 4 feet, at which point it is somewhat disturbed.

The pay-streak is difficult to trace. The average stoping-width is about 5 feet, and the ore is broken from the foot-wall, centre, or hanging-wall as the streak is followed. Shoots of ore occur between Nos. 1 and 2 shafts, giving an average of over 10 dwts. of gold to the ton; and picked samples have been taken which yield over 30 dwts. If the development of these shoots could be kept well ahead of the mill, to enable the management to bring up the average of the poorer ore treated, there would be no difficulty in obtaining a regular return of 6 dwts. per ton.

The former and present owners have extracted about 50,000 tons of ore from the mine.

Diamonds were reported by tributers to have been discovered in the battery-boxes of their mill, in 1893; they are stated to have been about 70 in number, of a greenish colour. Another diamond was reported as having been discovered cemented to a quartz-pebble. The tributers were of the opinion that the diamonds were located in a streak of small-pebble conglomerate, in the centre of the reef, in the vicinity of No. 3 shaft. This was, however, evidently not looked upon as a certainty, their

locality being considered still a matter for study, and samples were sorted from other sections of the mine, as well as those indicated by the tributers.

The ore, as it arrives from the mine, is delivered at No. 2 and No. 4 shafts' headgear, and thence by mechanical haulage up an incline of 250 feet, and tipped into the grizzly on the top floor of the crusher-house, at a height of 40 feet. The large ore falls into a No. 5 McCully crusher, which, with the fines from the grizzly, are passed into the revolving-trommel of $\frac{3}{4}$ inch mesh, the fines passing this trommel going direct to the ore-bins. The large ore that is retained passes to two No. 3 McCully crushers, the stuff from these crushers being elevated and passed through a trommel, the fines going to the ore-bins and the large ore feeding two Krom rolls, which in their turn discharge into the ore-bins.

The ore-bins are arranged so that the fines from the two trommels go into one ore-bin, and the coarser stuff from the rolls into the other. This arrangement has proved extremely convenient, as the stuff in the fine ore-bin contains a large percentage of gold, and the cyanide treatment can be arranged accordingly.

The fines from the crusher-house are delivered by mechanical haulage to the leaching-vats, and the residues from the vats to the dumps by the same means. The 8 leaching-vats have a capacity of 1,500 tons, when charged, the cyanide-stuff being allowed to percolate during an 8 days' treatment. The potassium-cyanide solution is delivered by gravitation to the extractor-house, passing from the leaching-vats through coir filter-vats to 4 extractor-boxes.

The extractor-house is fitted inside with two 3 inches centrifugal pumps, a zinc cutting-lathe driven by a motor, a roasting-furnace and two smelting-furnaces, and outside there are four solution-pumps.

The assay-office is close to the extractor-house, and is fitted with a complete assaying-plant.

On the mine, there are one storage-reservoir and one service-reservoir, with capacities of 500,000 gallons and 250,000 gallons respectively. Plans are being prepared for the establishment of a pumping-station on the Schoon spruit, and thus obtaining a permanent supply of water. In the past, arrangements had been

made with Niekerk, Limited, for a supply of water from their mine, whence it was pumped to the service-reservoir, a distance of 5,000 feet.

The wear-and-tear of the plant is satisfactory, and the rolls which crushed for some months wore but little on the tyres, and that little fairly regularly. The McCully crusher required overhauling about every third month.

About 300 tons of coal are consumed per month, and is delivered from the Orange River Colony, Prima Collieries, distant about 12 miles.

The expense of mining and milling (excluding development) are estimated to vary from 12s. 6d. to 15s. per ton of ore treated.

The success of the mine, considering the lowness of its grade, depends upon the largeness of its output, consequently an increased development of pay-ore and an extension of the vat-capacity is vital. The returns made are lower in value than necessary from want of the former; and the quantity could not be enlarged for need of the latter, notwithstanding the adequate crushing capacity.

The output during the months when the ore was being tested was as follows:—

Month.	Ore Crushed. Tons.	Gold Returned. Ounces
July	2,754	696½
August	3,049	736½
September	3,275	757¾
October	4,216	962½
November	2,807	563½
December	4,353	1,030¾
Total for 6 months ...	20,454	4,747½

The Niekerk, Limited.

This company are the owners of 217 claims or 319 acres on the townlands of Klerksdorp. The 217 claims are situated equidistant from the mining-properties of the Klerksdorp Gold and Diamond Company on the north and east, and from the Eastleigh mines and Roodepoort farm on the south and west.

The claims extend along the trend of the formation from 5,100 feet to 3,900 feet, and on the dip from 3,800 feet to 2,700 feet. They contain a portion of the auriferous formation that traverses the claims of the Commonage mine, the Klerksdorp Gold and Diamond Company's Little Mynpacht, and the Roodepoort farm.

The surface is mostly covered with a thin sheet of diabase, the exception being some 2,000 feet on the trend of the formation, where the sandstones are recognizable, and in which appear to be interbedded three separate conglomerate-reefs, though the southernmost may eventually prove to be the same reef as the middle one faulted to the surface by an overlap fault. This theory is, moreover, favoured by the similarity of conditions; but the northernmost reef of the three, being distinct both in regard to its matrix and surrounding country, is in all probability a separate body. The southernmost of these reefs is now being developed.

These conglomerate-reefs have been deposited upon a foot-wall of diabase: they have a sandstone hanging-wall, with a thin layer of shales intervening in places between the conglomerate and the sandstone. The matrix of the reef is composed of cemented quartzite-pebbles, with a diameter in some instances of 2 to 3 inches; these are for the most part smooth and rounded, although angular pebbles do occur; the larger pebbles are found near the foot-wall, and the smaller towards the hanging-wall.

From the presence of angular pebbles, and more particularly from the reef being deposited on a diabase-sheet, some writers have been led to correlate the Niekerk Reef with the Klerksdorp Black Reef. This deduction is purely theoretical, and it can hardly be considered sufficient to state that the Niekerk Reef is a divided portion of the Black Reef. From the indications given by the surface-outcrops of both reefs, they appear to be two separate reefs, traversing the country for some 3 miles parallel to each other, at about 5,000 feet apart and dipping in opposite directions. It cannot also be taken as a fact until further proof can be produced that because (until of late years) the Black Reef was the only reef with a diabase foot-wall mined in this district, that such will eventually be the case, and from the numerous igneous overflows, it is probable that other conglomerate-reefs may be discovered with either of their walls composed of diabase. The correlation of the Niekerk Reef with the Orkney mine formation, which is being worked to the south-west, on the Witkop farm, and others still further distant, must also be considered problematical until through further mining work more geological information is acquired to assist in their identification.

The Niekerk, Limited, are developing their mine by means of

three inclined shafts, sunk on the southerly or No. 1 reef, and one inclined shaft on the middle or No. 2 reef. A depth of 214 feet on the incline has been reached, and the reef for the first 50 feet dips at an angle of 47 to 70 degrees, after which it flattens to 30 degrees, faults at from 80 to 120 feet, and after the slide, it is found to be dipping nearly vertically. The first level has been driven at an average depth on the incline of about 100 feet down, and of 83¼ feet in vertical depth from the surface. The exact trend of the reef is north-east and south-west (Fig. 5, Plate XVIII.).

The mine, as developed, has been sampled and tested by assays, and the value of the ore is found to increase in depth. Special samples, taken in the north-easterly and south-westerly workings from time to time, have given the high results of 2 to 3 ounces of gold to the ton of ore; but taking the average obtained over 1,000 feet out of the 2,000 feet along the line of reef being developed (this omits some of the poorer ore of the outcrops and centre workings), an average of 9¾ dwts. of gold to the ton of ore may be expected. From a milling-test of 1,440 tons of ore, 9 dwts. 16 grs. of gold to the ton was obtained, at a mining-and-milling cost of 19s. 6d. per ton.

The mine is, however, as yet but in the early stages of its development, and there is a strong probability of the more valuable ore-shoots extending, and so increasing the average given, while the poorer zone of the central workings also shows improvement as greater depths are reached.

The No. 1 main shaft (14 feet by 5 feet inside the timbers) is 139 feet down on the incline, and is divided into three compartments:—one ladder-and-pumping-way and two skip-ways. It is close-timbered up to the face by cap-pieces, 9 inches square; sills, 6 inches by 9 inches; dividers, 9 inches by 9 inches; and lagging, 3 inches by 9 inches, the sets being spaced 5 feet apart, and each hung by eight hanging bolts.

No. 2 shaft (214 feet down on the incline) is 10 feet by 5 feet inside the timbers, divided into three compartments:—one ladder-and-pump-way and two skip-ways. It is close-timbered for 175 feet; from that point to the face the hanging-wall becomes sufficiently hard, and only sills are laid for the rails. The sets consist of cap-pieces, sills, dividers and side-pieces, 9 inches by 6 inches, and the lagging of 1½ inches planks.

No. 3 shaft, 132 feet down on the incline, and 6 feet by 5 feet inside the timbers, is divided into two compartments:—a ladder-and-pump-way and one skip-way. It is close-timbered for a length of 100 feet, and thence to the face sills are laid for the rails only; the cap-pieces, sills, side-pieces and dividers are all 6 inches by 9 inches, with lagging 1½ inches thick.

No. A1 shaft, 139 feet down on incline, has the same dimensions as No. 3 shaft, and it is close-timbered to the face.

When in full work, about 20,000 gallons of water are pumped to the surface daily, about 10,000 gallons of which have been delivered to the reservoirs of the Klerksdorp Gold and Diamond Company, Limited.

This mine has improved considerably with late developments, and the average thickness of the reef can be taken as high as 30 inches. From the firm nature of the country-rock after the fault described, there is every appearance of a continuity of the reef. At the present depth, the ore is still oxidized, and probably will continue to be so until the third level is reached. There are facilities for the construction of reservoirs, and a fair supply of water has been struck in the mine. There is a railway-station within 2½ miles.

The Eastleigh Deep, Limited.

The mining-claims of the Eastleigh Deep, Limited, are 781 in number, and cover an area of 1,148 acres on the Nooitgedacht farm, and to the south-east, and on the immediate dip of the mining leases of the Eastleigh Mines, Limited. Over the surface of the property are to be seen outcrops of compact limestone, beneath which are the quartzites and conglomerates of the Klerksdorp Black Reef formation, and underlying both is a sheet of diabase, the depth of which has not been ascertained. The estate is in places intersected by dykes.

Two vertical shafts have been sunk 500 feet apart, to cut at a deeper level the reef mined in the Eastleigh mine. No. 1 shaft, 16 feet by 5 feet, and 550 feet deep, has three compartments:—two cage-roads and one pump-and-ladder-way, and is timbered throughout. The shaft is 4,000 feet from the outcrop of the reef, the reef was cut at a depth of 472 feet, and an incline 10 feet by 6 feet sunk on the reef for 1,004 feet, to the south-east, at an angle of 9 to 25 degrees.

No. 2 shaft, 12 feet by 5 feet, has two compartments:—a cage-road and a pump-and-ladder-road. A dyke was cut in this shaft at a depth of 210 feet from the surface, and it followed the shaft down until a depth of 550 feet was reached. The reef having been found in No. 1 shaft, a cross-cut was started, and the reef was cut at 410 feet south-east of the dyke. Another cross-cut was also driven through this dyke to the north, and, on rising, the reef was discovered with a displacement of 40 feet. In the drive, 10 feet by 6 feet, connecting No. 2 shaft with No. 1 shaft, the reef was carried all the way, there being but a slight inclination (Fig. 6, Plate XVIII.).

In all places, where the reef was worked, the sandstone hanging-wall was found to be exceedingly hard, making an excellent roof, and no timber has been required in the mine, except for securing shafts.

The diabase forming the foot-wall is irregular, and in places it humps or bellies to such an extent that the whole of the quartzite disappears with the accompanying conglomerate; and then the diabase and limestone come into actual contact. In the incline, where the reef is not pinched out, the conglomerate-matrix averages about 1 foot in width, and assays of ore have given from traces up to 13 dwts. of gold to the ton. Towards the face of the incline, the reef shows a slight improvement.

The conglomerate-matrix is a cemented sandstone-grit with small smooth pebbles and quartz-segregations, and except in small pockets, no large smooth rounded pebbles are found, such as can be seen in the reef nearer the outcrop.

In consequence of the unsatisfactory results, the mine was closed, and the testing of the property by bore-holes was continued, four of which have been put down without satisfactory results. Under the best advice obtainable, an effort has been made to develop what at first sight appeared to be a mining property of great promise, but owing to faults and squeezes in the strata occurring at a depth at which it was expected that the Black Reef formation would be found in its entirety (a condition of things which could not be foreseen), the venture has up to the present failed to meet with success.

The diabase-sheet, previous to the deposition of the conglomerate, quartzites, and limestones in a section between a point above the Eastleigh boundary-line and a point west of No. 2

shaft, probably formed a comparatively high ridge, or perhaps a small hill. Consequently when the quartzitic and conglomeratic deposits found their level, this (then raised) ground was not covered by them, but was left protruding through them, to be afterwards covered by the limestones, which would account for the absence of the quartzites and conglomerates in portions of the mine, and the actual contact of the diabase and limestones. The fact that the incline at a distance of 1,004 feet from No. 1 shaft is in more likely conglomerate and quartzite than have hitherto been found, and that the incline is steepening as if leaving a ridge and making for a trough, leads one to hope that by advancing the drive or by boring to the south-east of the disturbed section described, a payable mine may yet be discovered.

Other Mining-claims.

The Southleigh Mines, Limited, possess 293 claims of 430 acres, about 4,000 feet north-east of the Eastleigh mines, and contiguous to the northern boundary of the Eastleigh Deep mines.

The reef is a portion of the Klerksdorp Black Reef, the average thickness is 6 feet throughout the mine, the foot-wall is diabase, and the hanging-wall quartzite. The conglomerate-matrix is similar to that in the Eastleigh mine; at a depth of 500 feet it is fairly hard, blue, and pyritic, but from that level to the outcrop it may be considered oxidized and friable. The gold is generally found in the lower 2 feet of the bed, but in the south-eastern drift of the first level, a shoot of ore appears, 2 feet thick, in the hanging-wall. The shoots of ore, so far as proved, give a promise of 9 dwts. of gold to the ton.

The main shaft, 13 feet by 5 feet, is sunk to a depth of 981 feet on the incline, it is close-timbered to a depth of 300 feet, and with sets to a depth of 400 feet, with deals 6 inches square. It is driven in the foot-wall of the reef, which dips at an angle of 8 degrees. Four levels were being commenced at 300 feet, 450 feet, 600 feet, and 750 feet, at the time when working was stopped.

The Eastleigh Block A Gold-mines, Limited, has 200 claims on the north-eastern boundary of the Eastleigh mines. An inclined shaft, 14 feet by 6 feet, has been sunk, and four winzes connected with levels at 260 feet and 400 feet, and a total of

3,000 feet of sinking and driving has been done. The reef, though rich in places, throughout the workings can only be considered patchy.

The Rand Investment Corporation, Limited, possess two properties:—one contiguous to the boundary of the Niekerk, Limited, and the other lies to the south-west of the Eastleigh mine. The former covers the extensions of the Niekerk Reefs to the westward, and on the latter excavations have uncovered a gold-bearing conglomerate-reef of considerable width.

The Klerksdorp Gold and Diamond Company, Limited, have sunk several shafts and made other excavations on their Little Mynpacht property (in extent 280 claims, or 411 acres), in which several conglomerate-reefs are exposed. Some of the reefs have been proved to be gold-bearing, but more cannot be said until practical mining has been undertaken.

On the eastern section of the Roodepoort farm, a certain amount of work has been done, and judging from the conglomerate-reefs discovered and the rich samples taken in places from them, it is certainly worthy of further attention.

General Remarks.

The Southern Klerksdorp gold-fields are favourably situated for the opening of further railway-communication with the neighbouring colonies. The extension of the Klerksdorp railway to Kimberley, and to Kroonstad in the Orange River Colony, may be expected in the near future, notwithstanding the apparent tardiness of the Kroonstad to Klerksdorp railway concessionaires. This latter line would be a great acquisition, as it would save the present detour *via* Johannesburg between these gold-fields and Cape ports; and as it is surveyed to pass through the heart of the Orange River collieries, it would cheapen the price of coal by at least 20 per cent.

The Klerksdorp Chamber of Mines has been a representative body of those interested in these gold-fields. A considerable amount of work has been done through the auspices of this Chamber towards the betterment of the local and general economic conditions. The present cost of mine-materials, foodstuffs, coal and labour was a few months ago lower than has been the case for some years, and general and development expenses were correspondingly reduced.

The control of mines by a dual board of directors (as is the case in some instances), that is, one in Europe and one in South Africa, is an unnecessary expense, often pernicious to the general interest of the mine, of little or no assistance to the mine-management, and could be advantageously substituted by a board of directors in Europe, and a local office in charge of a qualified consulting-engineer or managing-director of tried experience. This local representative should make periodical visits to the mines, report generally to the board of directors, and be accessible to the mine-manager whenever his advice and assistance might be required on matters of importance. Boards of directors in the Transvaal should have no difficulty in obtaining competent and trustworthy agents to represent their interests in Europe.

In conclusion, it may not be out of place to refer to the somewhat severe criticisms that the Klerksdorp, and more particularly the Black Reef mines, have of late been undergoing. The Black Reef formation has been unquestionably proved to contain deposits of ore, the grade of which is equal to that of several other formations. On it there are dividend-paying mines, and though at present it may be the fashion to point out the disabilities of such mines, it must always be borne in mind that from the early days of African modern reef-mining, there is hardly an exception of a present existing South African payable mining property that has not gone through at one time or other a similar damnatory detailed examination and review, and survived the ordeal. The matter of the greater mining cost attached to flat-reef mining, and to reefs with a dip of only a few degrees, in comparison to those with a steeper inclination, will in all probability be eventually overcome by the more extensive use of mechanical haulage throughout the mines, and the sinking of deep-level vertical hauling-shafts to connect with the inclined shafts from the outcrop; while the perfecting of the dry-crushing process means at least a 20 per cent. reduction in the cost of treatment. In fact, many well-written papers containing adverse conclusions upon the Black Reef of Klerksdorp, and the Barberton conglomerate-and-quartz gold-bearing reefs, written in Africa and published in Europe, almost savour of local prejudice, while such supposed poor zones as are (for instance) to be found along certain sections of the famous Main

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OMPANY, LIMITED.

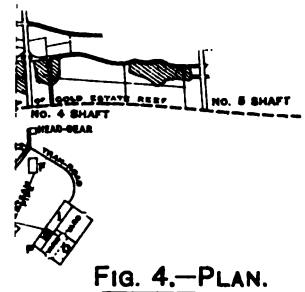
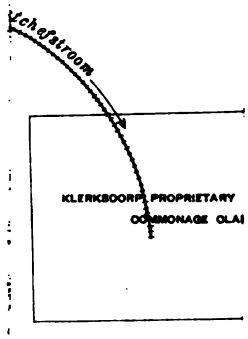


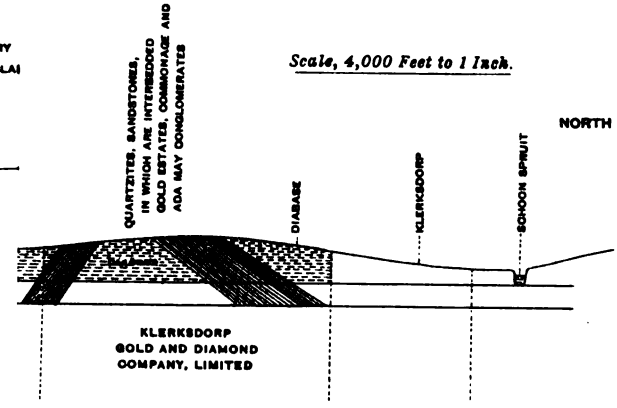
FIG. 4.—PLAN.

REFERENCES.

A. BOILER-HOUSE
B. CARPENTERS' SHOP
C. CRUSHER
D. COAL AND TIMBER SHED
E. DEPOSITING SITE FOR RESIDUES
F. ENGINE-HOUSE
G. EXTRACTOR-HOUSE
H. LEACHING VATS, 100 TONS
I. FITTERS' AND SMITHS' SHOP
J. ROLLS-HOUSE
K. SERVICE RESERVOIR, 250,000 GALLONS
L. SOLUTION TANKS
M. RETURN EMPTIES UNDER VATS
N. RETURN SECOND TREATMENT EMPTIES
O. RETURN TO TOP OF VATS, SECOND TREATMENT
P. STORE



Scale, 4,000 Feet to 1 Inch.


NORTH
QUARTZITES, SANDSTONES, IN WHICH ARE INTERBEDDED GOLD ESTATES, COMMONAGE AND ADA MAY CONGLOMERATES
DIABASE
KLERKSDORP
SCHOON SPRUIT
KLERKSDORP GOLD AND DIAMOND COMPANY, LIMITED

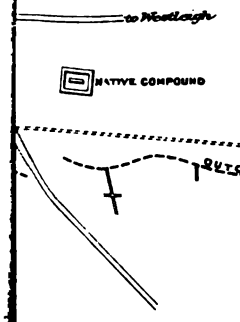
NDPAN

VNSHIP TO EASTLEIGH DEEP, LIMITED

SOUTH).

TLEIGH M

EASTLEIGH DEEP, LIMITED.



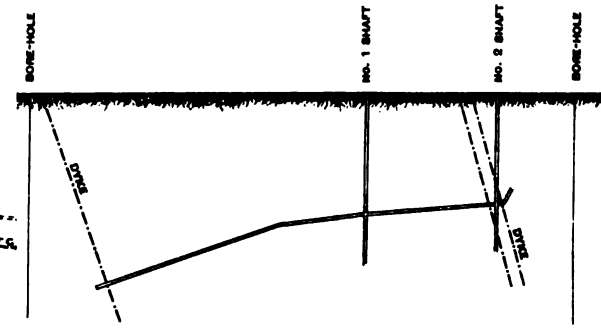


FIG. 6.—SECTION.

Scale, 500 Feet to 1 Inch.

Anst. Baird & Comp.y Ltd. Newcastle on Tyne.

Reef Series west of Johannesburg remain practically outside the controversy.

The Southern Klerksdorp reefs undoubtedly contain medium and low-grade ores, the successful development of which depends on a reasonable amount of capital being actually expended in the mines, and an improvement of the fiscal arrangements.

Mr. JOHN M. LIDDELL (Stocksfield-upon-Tyne) wrote that deposits of gold in payable quantities had been traced over a large part of the southern Transvaal. At Johannesburg, among many varied conglomerate-beds, it occurs chiefly or wholly in those which are grouped under the names of the South Reef and Main Reef; to the northward of the Rand, the conglomerate-beds are absent, and gold is nearly so; to the southward, gold is found extending in those conglomerate-beds called the Black, Elsburg, Nigel reefs, etc., until it reaches the Klerksdorp gold-field. The conglomerate-beds and strata about them vary much in thickness and character, and it does not seem probable that any given conglomerate-bed will be found to preserve its distinctive character for many miles. The gold-deposit occurs, generally speaking, upon beds of a clayey nature and covered by beds of a sandy nature; and it is a matter of careful prospecting to determine whether it is lying chiefly in one bed or more of conglomerate or other rock, at any given point in the field. In some cases, the conglomerate-bed is hardly represented at all, while at others, large beds and masses of it occur, through which the gold is so widely distributed as to be impossible of recovery. The relation of the conglomerate-beds to the gold-bearing veins of quartz, whether fissure-veins or interbedded-veins is not yet clear. Many of the quartz-veins found passing through the Johannesburg bankets are barren, but the semi-conglomeratic character of some of the richer and more important fissure-veins goes far to prove a close connection between them and the banket-beds. As the Transvaal gold-fields become developed, much further evidence on the method of gold-deposition should be acquired. It is a matter of general experience that the richest deposits of fissure-vein gold are found in cross-leads in the foot-walls of the vein. In the case of the Sheba reef-line, the foot-wall contained innumerable cross-leads of great richness, while the hanging-wall

appeared to contain no gold whatever. He (Mr. Liddell) suggested that the gold-deposits of the Rand were laid partly on unbroken bottoms of a clayey nature and in gravel and sand; and that there were probably some fissures in the foot-walls at the time of deposition, which would catch much gold and form rich foot-wall cross-leads, frequently unnoticed by men working on the conglomerate-beds. One such cross-lead was, he thought, found some distance to the north of Roodepoort, before the banket-beds attracted public attention from it, and from cross-leads generally.

The rates of wages and results in output now seem to be established on a reliable basis and to be fairly safe for estimates of future exploitations. The wages of white workmen are the result of recent conditions of life in the Transvaal, and the wages of coloured workmen depend upon the peculiar local conditions of the coloured labour supply. An additional comparative statement of results in tons of ore stoped per head per day, and of feet driven under conditions there obtaining, would be of great interest. He had usually found, on comparing averages of different classes of labour in different countries in regard to tonnages raised, etc., and wages paid, that earnings have varied with the quality of the labour, and that the cost per ton produced has been much the same. Thus, in using labour of half-price per head and half-effective value, it is necessary to double the amount of labour employed and to increase largely the amount of pit-room. He had found that wages on the Rand were generally similar to those quoted for the Klerksdorp district, but he had not found it profitable to trust the work of onsetting, banking, etc., to coloured men at coloured prices. He thought that a close study of the cost of substituting white for black labour throughout, under conditions soon to be established in the Transvaal, would reveal much in favour of white workmen from an economic point of view. The ore is getting steadily harder all round, and in hard rock, the better quality of labour is necessarily the more economical, apart from local questions of drink, disease, etc.

The tendency of Transvaal gold-mining is to increase the area of exploitations and that of the workings underground, and in consequence the size of the shafts. It is to be noted that rectangular shafts, containing much timber and many divisions, pumps, ladders, etc., are still in fashion. He thought that the question of ventilation failed to meet anything like adequate consideration. The dust from machine-drills and the fumes of

the dynamite used underground are excessive, and most injurious to workmen, and greatly hinder the work. An idea has been prevalent that a small pipe conveying air at high pressure to the working-face is the most effective means of ventilation, whereas the only effective method is to change continuously the whole volume of air wherein work or blasting is occurring, as is done in British coal-mines. In this view, it will be evident that a long narrow shaft (16 feet by 5 feet) divided into several compartments (pump- and ladder-way fitted with pumps, ladders, etc.), presents many hindrances to the passage of air. In proportion as costs of working are reduced, poorer ores will be worked and in much larger quantities, till something approaching the output of a British colliery is reached, and it may reasonably happen in flatter reefs that a shaft may last for many years and work large areas. It seems advisable therefore to use walling and iron-work in place of perishable timber, to construct the shafts with a view to more cage room, and less perimeter, dividers and other air-hindrances, and to dispense with ladders, which have long been obsolete in British collieries.

He thought that the question of the directorate was of capital importance to the progress of the industry and that the dual-board system was not desirable. It was a difficult matter for one person in London to appreciate clearly the conditions under which a second person in the Transvaal was conducting the operations of an intricate industry; much more so was it for one board to do so with regard to a second board, having regard to the difficulties of keeping the attendance at each board constant and unvaried, and of keeping the interests of all members of both boards permanently in unison. It was necessary for the success of any mine that one man on the spot should control all its operations himself, uninfluenced except by the formal instructions of a constant directorate. He should be able to call in whatever local advice might be desirable and obtainable, both for the working of the mine, and in order to make the whole operation clear beyond doubt to the directorate.

The Chairman (Mr. H. C. Peake) moved a vote of thanks to Mr. Hassall for his interesting paper.

Prof. H. Louis seconded the resolution, which was cordially approved.

DISCUSSION OF MR. M. WALTON BROWN'S PAPER ON "MECHANICAL VENTILATORS."*

Mr. Daniel Murgue (St. Etienne, France) wrote that he had carefully read the Report of the Mechanical Ventilators Committee with great interest. He need scarcely remark that he had been greatly honored by the Committee, who had followed in so careful a manner the method of making experiments which had been adopted by the Société de l'Industrie Minérale in 1878, and he wished to express his sincere thanks to the members of the Committee for their approval of his suggestions. He had no criticisms to offer respecting the carrying out of the experiments by the Committee and the method in which they had interpreted them, all being clear and correct. He might be permitted to remark that the Schiele, Guibal and Waddle types of ventilators, the subject of the Committee's experiments, appeared to be old-fashioned to French engineers. Following upon the investigations of Messrs. Mortier, Rateau and Ser, small ventilators of Schiele type were used in France: these produced an increase of the useful effect owing to the forward inclination of the vanes, and without being superior to the Guibal fan, they had the advantage of being less cumbersome. Owing to the adoption of the forward inclination of the blades, the formula, $h = u^2/g$ no longer represented correctly the theoretical depression; in fact, with the new arrangement, the depression may rise much higher, so that u^2/g could no longer be considered as a depression of comparison. The 1878 Committee of the Société de l'Industrie Minérale were not acquainted with this type of ventilator, so that they could take the theoretical depression, u^2/g, of the ventilator with radial blades as the maximum depression which could not be exceeded, but this opinion was no longer correct. The manometric efficiency was therefore only a ratio of comparison, and it might become greater than unity.

Mr. H. W. G. Halbaum (Gateshead) thought that too much praise could not be accorded to the Committee and to Mr. M. Walton Brown for the immense amount of labour and research which they had brought to bear upon the elucidation of a most difficult question. Only those who had devoted any considerable attention to the subject could form any idea of the many peculiar

* *Trans. Inst. M.E.*, vol. xvii., page 482; and vol. xviii., page 488.

difficulties attaching thereto. There were some little matters on which he did not find himself in absolute agreement with Mr. M. Walton Brown, but in face of the great value of the work generally, it would be ungracious to refer to these very minor points at any length, and probably, after all, Mr. M. Walton Brown and the Committee were right, and he (Mr. Halbaum) wrong. He would like, however, to refer briefly to one or two points of practical interest which seemed to be accentuated by this *Report*. One lesson, he thought, was that the real water-gauge was very difficult to obtain. In Appendix B, Table 2, No. 1 experiment, for example, it was stated that the return airway to the ventilator was closed, with the exception of an opening of 3 square feet, yet according to the observed water-gauge and the measured volume of air, the equivalent orifice was 4·04 square feet. It would, of course, be evident that the actual equivalent orifice in such a case could not be greater than 3 square feet, and according to Mr. Murgue's theories the equivalent orifice should have been no greater than (3 × 0·65 =) 1·95 square feet. In the same Table, No. 4 experiment, when the orifice in the return was adjusted to 6 square feet, the equivalent orifice of the mine, calculated by the water-gauge and volume of air, was 10·09 square feet.* It thus appeared that the data of the observed water-gauge and volume were insufficient to estimate the true equivalent orifice of the mine, for the water-gauge, as observed, failed to account for the mere velocity of the observed volume through the contracted area of 6 square feet set up in the return airway. The same apparently insuperable difficulty in getting the true water-gauge would be seen in several of the other tables of the same series. In connexion with this matter, it would also be seen that in some cases the effective depression h was observed to be greater than the initial depression estimated by the Committee. For example, in Appendix D, Table 30, it was stated that H = 2·421 inches; but the third experiment in that table gave h, which was only one part of H, a value of 2·616 inches;† in Table 34, No. 2 experiment gave h as 0·202 inch greater than H; which, of course, was an impossibility; but it illustrated some of the difficulties attaching to these investigations.‡ He thought that the water-gauge was, with regard to its position, a most important considera-

* *Trans. Inst. M.E.*, vol. xvii., page 523.

† *Ibid.*, page 572.

‡ *Ibid.*, page 574.

tion in such experiments, and he did not think that the experiments of the Committee, as tabulated, bore out the views of those who thought that the inlet of the fan was the best position in which to place the water-gauge.

Some of the tables showed, or seemed to show, that the mine could be shut off and not shut off, at one and the same time. For example, in Appendix B, Table 4, No. 1 experiment was stated to have been made with the return airway to the ventilator closed, but the mean volume of air was said to be 23,924 cubic feet per minute and the equivalent orifice of the mine to be 7·081 square feet.*

The Committee had proceeded upon the assumption that Mr. Murgue's orifice-theory was reliable, and he believed that, although it had its limits, certain of which were named by Mr. M. Walton Brown, it was the best theory at present available for use in fan-tests. Considered *per se*, it was simplicity itself. But it was to be regretted that Mr. Murgue had presented the theory to mining-engineers in so unmanageable a form. One result of this presentment was that the Committee had put themselves to infinite trouble such as might, in his view, have been avoided, had they treated the theory from a graphic instead of from the less simple standpoint adopted by Mr. Murgue. Mr. Murgue had resorted to the calculus to prove things that were already obvious; he had entered into abstruse calculations to prove what might much more easily have been proved by drawing a straight line. He had plotted circles by ordinates and co-ordinates instead of describing them with an ordinary compass, and had plotted lines at right angles, which ought to have been drawn parallel. By this means, the usefulness of his theory had been regrettably hindered, and such investigations as those recorded by the Committee had been rendered unduly laborious and complicated. It was stated that the connexion of the volume and depression with the equivalent orifice of the mine could not be easily explained. But by Mr. Murgue's theory, cast in its proper form, the volume, the depression and the equivalent orifice had precisely the same simple connexion as the sine, cosine and tangent of a given angle. And, as a matter of fact, the mechanical efficiency was but another function of the same angle, and by merely drawing a quadrant of radius 4, a semicircle of radius 2,

* *Trans. Inst. M.E.*, vol. xvii., page 530.

and a circle of radius 1, the whole of these values could be determined for any given fan by simply drawing a straight line and noting the points at which it cut the quadrant, the semicircle and the circle respectively. By this simplification, it was possible, in respect of any fan on any mine, to find out by not less than two and not more than four experiments all that could be determined about that fan. The geometrical complexion of the whole problem was visible in Mr. M. Walton Brown's equation (24),* for $a^2 + o^2$ was merely the square of the diagonal of the rectangle formed by the sides a and o; whilst $\frac{o^2}{a^2 + o^2}$ was equally the square of the cosine of that angle where o was the radius and a the tangent, or where $a = o \tan \angle$. Then, again, the volume of air was a constant ratio of the product $a\sqrt{h}$, no matter how a and $\sqrt{h}$ might vary. Therefore, the volume was a constant ratio of the product of the tangent and cosine of the angle named. But $\tan \angle . \cos \angle = \sin \angle$, and therefore the quantity of air was a constant function of the sine alone. Engineers would see that the labours of this Committee would have been marvellously simplified had Mr. Murgue presented the simple theory of the equivalent orifice in the equally simple shape which it naturally assumed when reduced to a geometrical form. They would see that the real characteristic curve for any fan, properly drawn, was the arc of a true circle, and the only thing which imparted "character" to such a curve was its radius. For any fan, it could be proved that the differentiating factor in the radius of the curve was $o\sqrt{K}$, to follow Mr. M. Walton Brown's notation. And from this, again, they would perceive that in order to find the radius of the curve for any fan, it was quite unnecessary to provide the five factive mines demanded by Mr. Murgue's method, nor was it necessary to extend the experiments to 7, 8, 10 and 11, as the Committee did. For by Euclid, "three points on any circular arc completely determine the position and magnitude of the circle to which it belongs."

No engineer appreciated the work of the Committee or valued the results obtained by them more than he did, but he could not help recognizing that their labours might have been lightened and their results, in his opinion, would have been intensified in value, and would, moreover, have been more easily appreciated by the ordinary practical man, had the equivalent-orifice theory

* *Trans. Inst. M.E.*, vol. xvii., page 512.

been originally put before the mining-engineers of this country in the simple shape which he had pointed out as being its most obvious and most natural form.

Mr. S. L. Thacker (Walsall) wrote that, as a contribution to the literature on the theory of mine-ventilation, this *Report* was an undoubted acquisition, and the formulæ and data contained therein, taken in conjunction with the results of the experiments, seem to be a verification of the theory of centrifugal ventilators as put forward by Mr. D. Murgue. Mining-engineers had been looking forward to the publication of this *Report*, expecting to find therein a definite settlement of the question, whether the old type of large and slow-running fans, or the smaller and high-speed fans of later date were the more efficient; and which, taking into account first cost, maintenance and repairs, would give the highest return for the original outlay. The fact of the answer to that question being confined in the *Report* to Guibal, Waddle and Schiele fans was somewhat disappointing, especially as only the Schiele fans were of modern construction. If the total resistance of any mine can be reduced to an orifice in a thin plate, and if the final measurement of the efficiencies of the fans is given by the characteristic curves plotted with those orifices as abscissæ and the volumes of air at normal velocity as ordinates, wherein lies the absolute necessity of only comparing two or more fans running on the same mine?

If the Committee would place themselves in communication with the makers of modern Capell, Chandler, Schiele, Waddle, Walker, and other fans they would, he felt sure, meet with every co-operation and assistance in the carrying out of thoroughly impartial tests of modern fans, either at the works of the makers or at mines where such fans had been recently installed. Such a series of tests would remove the errors due to driving by old and inefficient steam-engines: a point of considerable importance. If the Committee issued a supplemental report of experiments made somewhat upon these lines it would, he thought, add greatly to the usefulness of their labours.

Mr. T. H. C. Homersham (Bradford) said that the *Report* of the Committee, although most exhaustive, would, he was afraid, not be of very much assistance to the mining-engineer in his selection of the most suitable fan for his individual requirements, but it was most interesting to those concerned in the design of centrifugal

fans, although the actual comparison of the various types seemed to him to be of very little value, as the Committee appeared to have entirely neglected the very important consideration of the specified duty for which each fan was designed. For instance, at Cwmaman colliery, a Guibal and a Waddle fan were tested at the same periphery-speed, although there could be very little doubt that the Waddle fan was erected for a very much higher duty, as the engine driving it was nearly five times as large as the engine driving the Guibal fan.

He (Mr. Homersham) did not agree with the inferred axiom that " the results obtained by different fans can, however, be compared with accuracy if they are tested at similar circumferential velocities."* A high mechanical efficiency was quite compatible with a low manometrical efficiency, and it was quite possible that the designers of the fans tested had very different circumferential velocities in view from that of 6,000 feet per minute, which, it seemed to him, had been somewhat arbitrarily fixed by the Committee. He considered that the superior results obtained with the Guibal fans over those of more modern design were largely due to the fact that the conditions under which the tests were made were very much more in accordance with the requirements exacted of the Guibal fan at the date at which most of the fans were erected. In any case, he should be reluctant to think that all the old Guibal fans, which had become worn out, had been replaced at the expense of mechanical efficiency. It seemed to him that it was not necessary to confine the tests to mines where there were two fans of different types; that a perfectly fair comparison could be made or at least as fair a comparison as the *Report* supplied, if the resistances of the two mines were brought into conformity with each other. It would, he thought, have been desirable to test the fans independently of the engines driving them, as it was rather late in the day to test engines of the various types described. It was curious, however, to note that no measurements had been made of the steam-consumption of the engines, and he failed to see what value could attach to tests made without that information, so far as the value of the combined plant was concerned.

A large amount of time and trouble had been devoted to the preparation of characteristic curves of the fans, but he did not think that these curves were of any practical use to mining-

* *Trans. Inst. M.E.*, vol. xvii, page 484.

engineers. A mining-engineer specified the temperament of his mine by stating the volume of air that he required and the resistance of the mine to the passage of that volume; the makers then designed a fan for those conditions. The error throughout the *Report* lay in the fact that, apparently, the Committee failed to take into consideration the duties for which the fans were designed and the speeds at which they were intended to run.

He thought the inference drawn from these experiments that the highest mechanical efficiency of the fans tested might be realized upon mines having equivalent orifices varying from 35 to 40 square feet, beyond which the useful effect began to diminish, was fallacious.* He did not dispute the accuracy of the figures given by the Committee; and he had no doubt that it was the case with the fans tested, because in all probability those fans were designed to a specification representing an equivalent orifice of that size; but that was no proof, however, that a fan could not be designed to work equally or even more economically on a mine having a large equivalent orifice. He also thought that the members would fall into a serious error, if they assumed that the Guibal fan was the most economical type of fan, and that the highest obtainable mechanical efficiency was 55 per cent. of the indicated horsepower.

He (Mr. Homersham) suggested that the Committee should invite each maker to name one of his fans working on a mine; that the fans should be tested only under the conditions for which they were supplied; that experiments should be made to ascertain the actual brake-horsepower as well as the indicated-horsepower; and, in a series of tests in order to ascertain the efficiency of the fan and engine, that the steam-consumption of the engine be ascertained. If the experiments were carried out in the manner that he had suggested, he was sure that the Committee would arrive at a more satisfactory result than that the fans, which had replaced the Guibal type, were inferior to it in efficiency. He would be surprised to find that many of the members were of that opinion, and he believed, if modern fans had been tested, that the results would have been of more practical use. He was certain that all makers of fans would willingly assist the Committee in making any further experiments, if requested.

* *Trans. Inst. M.E.*, vol. xvii., page 507.

Mr. C. C. Leach (Seghill) said that makers usually desired to drive a fan by an engine very much larger than actual requirements. He had erected a fan of Waddle type; the makers proposed to drive it with an engine having a cylinder-capacity of 600 cubic inches. As a matter of fact, the engine had a cylinder-capacity of 200 cubic inches, and that was, in practice, found to be of too great capacity. He had indicated many fan-engines, and he found that a boiler-pressure of 80 pounds and upwards per square inch was usually throttled, so that the initial pressure in the cylinder rarely exceeded 8 to 10 pounds.

Mr. W. D. Wight (Pontypridd) remarked that the Waddle fan-engine at Cwmaman colliery was to a great extent an experimental one. As stated in the *Report*, the engine driving the fan was a marine engine bought for another purpose; the conditions required were that the Waddle fan should be capable of producing double the volume of air produced by the existing Guibal fan, and this necessitated the Waddle fan being driven at a higher speed at a greater expenditure of power. Under ordinary working conditions, the Guibal fan, at 60 revolutions exhausted 80,000 cubic feet per minute at a depression of $1\frac{3}{4}$ inches of water; and the Waddle fan was erected to produce double that volume, at 7 inches of water-gauge, when running at 130 revolutions per minute. Another engine, more suitable for the purpose, had been applied to drive the Waddle fan, after the Committee had concluded their experiments.

Mr. T. H. C. Homersham remarked that, as the Waddle fan had been erected to work at a water-gauge of 7 inches, it should have been tested by the Committee, when working at that depression.

Mr. Henry Hall (H.M. Inspector of Mines) said that the fan-question had always struck him as being a difficult one. Two Waddle fans, 30 feet in diameter, were being fitted on the same shaft, similar to the paddles of a steamer, at a Lancashire colliery, and the manager expected that the volume of air would be largely increased in consequence of using two fans instead of one. Perhaps Mr. M. Walton Brown could give him some idea as to the increased volume of air that would probably be produced under such conditions; as it had always been considered that very little advantage would be obtained by running two fans side by side.

The Rev. G. M. CAPELL (Passenham) said that he had read and studied the question of testing fans, and he had seen the great difficulties which the Committee had tried to overcome. The Committee restricted their experiments to mines where two fans of different type were erected side by side, upon the same upcast shaft, in order that tests should be made of the actual duty of the fans when working under actually similar conditions. From his own experience, he knew that it was remarkably difficult to find two mines whose conditions were exactly the same; and he agreed with the Committee that, to obtain, where possible, absolute comparison between the two fans, they should be tested under similar conditions on the same upcast shaft.

In the case of an open-running and an enclosed fan working on the same mine, the manometric efficiency of the open-running would naturally be less than the close-running fan; and as the normal periphery-speed was fixed at 6,000 feet, it was a foregone conclusion that the open-running fan could not possibly compete with the enclosed fan under that condition. The open-running fan might, and had proved to be, in the case of the Waddle fan, a strongly constructed fan capable of running with much more safety on account of its narrow width and form than the more ponderous and wider Guibal fan.

Some of the fans tested by the Committee were rope-driven or belt-driven, and they were compared with fans which were driven direct. The loss by belt-driving at a fair speed varied from 10 to 15 per cent., and the comparison of the useful effect of a belt-driven as against the direct-driven fan required some allowance.

There was difficulty in measuring the brake-horsepower applied to a fan-shaft, and he did not think that it was necessary, in comparing plant, to measure it. He preferred to ascertain the "mechanical efficiency of the whole plant," in which the indicated horsepower was compared with the horsepower utilized in the air. The saving of steam and of fuel did not depend upon the engine and the fan, but varied with the fan, the engine and the boiler.

He (Mr. Capell) had pleasure in stating that the trials and tests made by the Committee were the most complete that he had ever seen, and their successful execution must have entailed an enormous amount of trouble on the Committee. He regretted that the types of fans, on which the experiments were made, were

not of more modern design, but as the tests were to be continued on more modern fans it was perhaps not worth while to allude further to the matter. He hoped it would be possible for the Committee to arrange to test some of the fans, capable of producing high depressions, up to 10 inches of water-pressure.

Mr. A. L. STEAVENSON (Durham) said that he had always held it to be the duty of the mining-engineer to prove, as he went through life, the value of all the apparatus and machinery which he was called upon to use; and so it came about that he had made tests upon the different fans which came within the scope of his influence, and the result was that about 15 years ago he satisfied himself that practically no fan was superior to the Guibal fan. Since that time other fans had been introduced, for which very great merits were claimed, but he had never been able to satisfy himself that any of these fans were superior in efficiency to the Guibal fan. He approved of the manner in which the experiments upon fans had been carried out by the Committee, of which he was a member, and if any maker of fans was dissatisfied with the *Report*, which had been written by Mr. M. Walton Brown, the Committee would be pleased to test the fan in their own way. Although he was of opinion that the Guibal was the most efficient fan, smaller fans were considerably cheaper and had other advantages, which induced mining-engineers to adopt them under certain conditions.

Prof. H. LOUIS (Newcastle-upon-Tyne) remarked that in testing fans, it was obvious that some standard method must be adopted. One critic alleged that the normal velocity of the periphery of the fan, adopted by the Committee, was too high, while another said that it was too low, but who was to decide which was right? The Committee, however, in addition to experiments at a periphery-speed of 6,000 feet per minute, had made almost as many experiments at higher and lower speeds, and especially at the speed at which the fan was ordinarily accustomed to work. The results of the experiments had, however, been reduced by well-known mathematical methods, for purposes of comparison, to a common measure. The Committee was still in existence and anxious to make further tests on modern fans, so that if further reports were not forthcoming, the discontinuance would be due to the refusal of the owners or makers of fans to allow them to be tested.

Mr. J. A. Longden (Stanton-by-Dale) said that there was no doubt a distinct difference in the efficiency of open-running and enclosed fans, and there was an equally distinct difference in their respective costs. With regard to the use of two fans exhausting from one shaft, he had two Waddle fans (each 40 feet in diameter) at Pleasley collieries, running together on the mine, and no more air was produced by running both than running one singly; but there was a greater horsepower, because two engines were running for the same work.

Mr. S. F. Walker (London) remarked that whatever machinery was used for doing work at mines, it was essential that the amount of coal consumed at the boiler or the amount of steam which was taken by the engine which drove it, should be as small as possible; and that the method of connecting the engine mechanically to the machine, the machine itself, and the apparatus that it worked, should each be as efficient as possible. Otherwise if they had, for instance, an engine of low efficiency, the efficiency of the entire plant would be decreased. He thought that Mr. Capell placed the efficiency of belt-driving lower than it should be, but if power was wasted in belt- or rope-driving, the fan or other machine-plant must be consuming more steam or coal than would otherwise be required. In testing any machine, no matter of what kind, there was probably no more simple plan of measuring the motor-power than applying an electric motor to it and taking readings of the electric meters. A dozen or more readings, representing as many different conditions of working, could be made practically as fast as they liked, and within considerable limits they would be absolutely accurate.

The Rev. G. M. Capell said that the object of a fan-test was to compare the actual horsepower driving the fan with the horsepower utilized in the air, but if they went into the plant-efficiency it was necessary to measure the efficiency of the engine as well as that of the fan. For instance, at one colliery he might find a fan driven by a small engine, and another by an engine too large for its work; a more modern fan driven by a compound engine; and a fourth fan might be driven by a compound condensing engine. Necessarily the coal-consumption would differ largely for the same volume of air at the same water-gauge.

Mr. Arthur Sopwith (Cannock) remarked that the battle of

the fans had been going on for many years and would continue for many years to come. A more important subject than the efficiency of the fan was that of having the mine so efficient that they could utilise to the greatest advantage the efficiency of the ventilation. It was desirable to make a plan of a colliery on the same system as a traffic-map, and starting from the downcast shaft to draw a sketch showing the volume of air at all the different parts of its course. They would find many astonishing results, which would give rise to many questions as to leakages of air, not necessarily through doors, but actually through what was deemed to be solid rock. There was enormous room for saving considerable volumes of air, which would more than equal the slight difference in the efficiencies of fans.

Mr. M. Walton Brown replying to the discussion said, with regard to the ages of the fans tested, that although the Guibal fan shewed the highest efficiency apart from the engine, it also showed the highest efficiency including the engine, but this was mere coincidence. Of the four Guibal fans tested, with one exception, they were 9, 14 and 15 years older than the Waddle and Schiele fans against which they were tested, and therefore the probability was that if a modern Guibal fan was tested against these fans, it would show a much higher result. Mr. T. H. C. Homersham said that if a mining-engineer specified his requirements, the manufacturer would design an efficient fan to suit those requirements; but the curves drawn on the plans attached to the *Report* would show the mining-engineer whether his requirements were such as to secure reasonable economy in the working of the fan after it was erected. If he had a contracted mine he should endeavour to enlarge the airways and erect a fan suitable for the enlarged airways. Recently, with an expenditure of less than £1,000, the airways of a mine had been considerably improved, and that amount would be speedily recouped by increased economy in the working-cost of the fan. The makers of a fan should always be carefully advised as to the exact requirements of the mine, in order that they might make the most suitable fan.

In making the experiments, the Committee had carried out their own scheme without reference to the work for which the fans might be designed by the makers, and experiments had also

been made on the fans when ventilating each mine under ordinary working conditions.

Mr. H. Hall had referred to the use of tandem or parallel fans. In either case, he believed that the result would be about the same, and two fans would theoretically produce about 41 per cent. more air than either of them would produce singly. The late Mr. J. J. Atkinson made experiments upon two Guibal fans at the Duffryn collieries and Mr. W. Cochrane had reported the results to the members.* The experiments were made with the ventilators both in series and in parallel, and the result was about the same in each case, namely that the two fans, working together, produced about 35 per cent. more air than a single fan.

Objections had been made by Mr. T. H. C. Homersham, that all of the experiments had been made at the normal speed of 6,000 feet a minute, but if he referred to the *Report*, he would see that some of the fans had been tested at speeds as high as 10,323 feet per minute, and more experiments would have been made at higher speeds, if the engines had been of sufficient power. When the fans were run at higher speeds the mechanical efficiency was usually greater than when run at lower speeds; and he had recorded a few typical cases in his *Report*, in which the speed of the fan and its corresponding mechanical efficiency were compared. Some of the fans appeared to have a critical speed, above which the mechanical efficiency began to diminish.

Mining-engineers, who objected to the equivalent-orifice theory as a means of comparing the relative efficiencies of fans, could refer to the *vidimus* attached to each table of experiments, and use the results to support their views. The same table contained a calculation of the volume of air produced per revolution of the fan, and these results showed that this volume might vary as widely as the conditions, from one to twenty-fold for the same fan.

The Committee were willing to make experiments upon suitable fans, if mining-engineers or the makers would send the results of experiments to the secretary, as the Committee did not wish to test a fan and find that it gave lower results than other fans which had been already tested.

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* *Trans. Inst. M.E.*, 1891, vol. ii., page 483.

PRACTICAL APPLICATIONS OF THE PROCESS FOR THE PRODUCTION OF HIGH TEMPERATURES BY THE COMBUSTION OF ALUMINIUM.*

By Dr. HANS GOLDSCHMIDT.†

Two years ago, the writer introduced a new process for the production of high temperatures. Meanwhile, the practical applications thereof have been energetically worked out, so that he is now in a position to give fuller information respecting a few of the results obtained.

The purely metallurgical side of the process, namely, the production of metals free from carbon, and more particularly of chromium and manganese, had in the first place to be introduced and adapted for operations on a large scale. The Société d' Electro-Chimie of Paris, which has acquired a license to use this process, has been producing the above-named metals for about a year, whilst the remaining industrial demand is supplied by the Allgemeine Thermit-Gesellschaft of Essen. The production takes place in large, crucible-like vessels, in which a few hundredweights of metal are separated in each operation. On account of the rapidity of the reaction, this occupies barely ½ hour.

While carbon-free chromium is especially used in the manufacture of steel, pure manganese finds an application in the production of pure (iron-free) cupro-manganese. The old observation has again been repeated in the case of these two metals, that pure or practically pure metals have different properties from those which they possess when combined with various kinds of impurities; further, that such pure metals present certain advantages, and in the special cases before us, have a considerably higher technical value also when employed in the form of alloys.

In steel-making, chromium has hitherto been used in the form of ferro-chrome, containing from 40 to 65 per cent. of chromium.

* "Einige technische Anwendungen des Verfahrens zur Erzeugung hoher Temperaturen durch Verbrennen von Aluminium (Aluminothermie)," *Zeitschrift für angewandte Chemie*, 1900, No. 37.

† Translated by Prof. Henry Louis, M.A.

This product generally contains some 12 per cent. of carbon, calculated upon the chromium contents. The chromium is not, therefore, present as such, but merely as a carbide. Steels produced with the aid of this carboniferous ferro-chrome are, strictly speaking, not chromium-steels, but chromium-carbide steels. With pure chromium, free from carbon, different alloys can be produced, which have also different properties, and above all are softer and less brittle. It is, moreover, possible to produce with the pure chromium, mild steels containing a higher percentage of chromium than has hitherto been attainable, because the high carbon contents of the ferro-chrome made it impossible to produce alloys high in chromium on account of the high percentage of carbon that would be simultaneously introduced. Chromium free from carbon has therefore special interest for the steel manufacturer, because it alone makes feasible the accurate study of true chrome steels.

The advantages gained by the introduction of carbon-free chromium is rendered evident by the commercial production of this metal in the manner above explained on a large scale, which has been necessitated by the numbers of works employing it.

As regards the price of this pure chromium containing about 98 per cent. of metal (the remainder being chiefly iron and a few per cent. of silicon), it is in correct proportion to the 60 per cent. metal, the chromium in it costing about twice as much as the chromium in the 60 per cent. alloy. It is well known that the chromium in the 40 per cent. ferro-chrome costs about half as much as it does in the 60 per cent. alloy.

The main applications of manganese free from carbon are at present of an entirely different nature, the iron and steel manufacturer having made but little use of this substance. The chief reason is that manganese produced by means of aluminium is considerably higher in price than the ordinary ferro-manganese which is smelted at small cost in the blast-furnace, the proportion of cost being about 10 to 1.

On the other hand, copper-smelters have employed, for some time past, pure manganese on a large scale and with great advantage. The benefits obtained by the use of carbon-free manganese, as compared with the product containing carbon could not be predicted, seeing that the carbon-contents of the manganese

have no direct effect upon the copper. The carbon is either slagged off or burnt off, no carbide of copper being formed.

If, as is usually the case, a ferro-manganese is used containing some 80 per cent. of manganese and 8 to 9 per cent. of iron, the remainder being carbon and impurities, an amount of iron equal to about 10 per cent. of the quantity of manganese added is always introduced into the copper. Accordingly, an ordinary cupro-manganese containing about 25 to 30 per cent. of manganese always contains from $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent. of iron. In order to obtain cupro-manganese free from iron, it is necessary to employ manganese free from iron. Manganese free from iron can be produced by the wellknown method of reduction in a crucible, by means of carbon; the product is, however, a carbide of manganese, which, when exposed to the air, rapidly crumbles to powder. The manganese free from carbon produced by the aid of aluminium has the advantage that it may be kept exposed to the air as long as may be required; it only oxidizes a little superficially, but less even than iron. This carbon-free manganese is distinguished by the avidity with which it forms alloys. Fragments of such manganese projected into a crucible of copper, alloy with it with the greatest facility, almost without the formation of any scale, although this is always produced when ordinary ferro-manganese is used. In this very simple way alloys of copper containing 30, 50 and even higher percentages of manganese can be produced. These alloys, rich in manganese, are then used for again alloying with pure copper. Alloys of zinc and tin with manganese can be produced in the same simple manner.

In spite of the considerably higher price of this pure manganese compared with ferro-manganese, the former is preferred for the production of high class manganiferous copper castings, because it has been proved by means of comparative experiments carefully made on a large scale that sound castings, free from porosity, can only be produced by the aid of this metal. An alloy of copper with 5 per cent. of manganese (which scarcely alters the colour of the former) has particularly come to the front, because it has been found to possess high resistance to change of structure, especially when exposed to hot furnace gases. Rods and tubes are made from this alloy.

Recently great interest has been shown in various quarters in

the production of ferro-titanium; even small additions of titanium—a few tenths per cent.—communicate a particularly dense and fibrous structure to iron or steel. Experiments with ferro-boron, on the other hand, have for the present made no advance. The application of vanadium, on the contrary, seems likely to yield very good results, as vanadium steels appear to possess quite exceptionally good qualities so far as the experiments hitherto carried out are able to show.

Considerable advance has been made in the treatment and utilization of the corundum, which is produced as a bye-product in the process, and which has been introduced as a commercial article under the name of "corubin." It is especially adapted for use as an abrasive, and has also been employed as a fireproof material.

The most important, and the most varied applications of the process are those which depend upon the utilization, in the heat treatment of metals, of the heat developed by the reaction. The possibility of employing this heat in various ways was sufficiently obvious, so soon as experiment had proved that such large quantities of heat could be evolved without employing any external source of heat; but two years ago it was not possible to quote any really practical applications. A whole series of difficulties had to be overcome, before it was possible not only to introduce, but in the first place to discover suitable applications of these high temperatures. In the first place, it was necessary to study thoroughly the action of the metal in the crucible, and especially to obtain the conviction that its use was attended with a complete absence of danger from fire. It was soon found that the worst that could happen would be the cracking of the crucible containing the melt at a temperature of 3,000° Cent., but, the molten mass sets almost at the very instant that it leaves the crucible; and as the corundum is immediately cooled below its freezing-point, it at the same time encloses the greater portion of the metal. Very few sparks are thrown out, and even these only appear when the mixture is being ignited, and are then free from danger. It is worth noting that the mixture is not liable to spontaneous combustion, nor can it be ignited by percussion. As soon as any of these mixtures becomes wet, they entirely lose their property of burning; at the same time a small amount of moisture absorbed

from the air does little or no harm, though it is proper to keep these mixtures in closed vessels.

Various experiments have shown how energetic is the effect of metal molten by means of aluminium. For example, Fig. 1 represents a block of iron about 10 inches in height which has been cut through to about one-third of its depth by a groove 1 inch wide, by allowing such aluminothermic iron (after the layer of corundum above it has been poured off) to run over the edge of the block. Bars of hard steel, 1·6 inches square, laid side by side, were melted through by means of a few pounds of thermite within a few seconds. In the same way, thick iron and steel plates, and even armour-plates, have been perforated.

FIG. 1.—BLOCK OF IRON, 10 INCHES THICK, MELTED ONE-THIRD WAY THROUGH, BY POURING ALUMINOTHERMIC IRON UPON IT.

The great difficulty was to find a means of suitably conveying the heat generated to the metal to be worked. It was fairly obvious that the best way of conducting the process was, not to introduce the pieces of iron into the crucible, but on the contrary to pour the molten corundum upon the metal. In the first place, it had to be proved that the corundum, together with the other contents of the crucible, could be easily poured out and that its handling was safe and free from danger. This had, of course, to be proved experimentally: it was thus shown that the molten mass could be poured out almost in its entirety, that but little of it was

left clinging to the sides of the crucible, and that above all the same crucibles can be used repeatedly.

The production of suitable crucibles proved a source of much labour and difficulty, as none of the crucibles hitherto in use were suitable for this purpose, their siliceous walls being immediately dissolved by the fluid alumina. The only crucibles that can be employed are lined with magnesia or alumina, and manufactured by the Allgemeine Thermit-Gesellschaft.

It was found practicable to weld iron bars by clamping these firmly together, strongly heating the point to be welded, and taking care at the same time that the clamps remain cold. The elongation of the iron bars due to the heat produces sufficient pressure to effect a weld. The first experiments on welding were performed in an apparatus of this kind; a little mould of sheet-iron was built round about the part to be welded, lined with moulding sand, and the molten corundum was poured into the cavity thus produced. Square and round iron bars could thus be welded perfectly, as was shown by bending-tests of the welded bar, but the method was far too expensive for practical purposes.

The facility of the process and the portability of the apparatus suggested the possibility of welding not only outside the smithy, but moreover quite irrespective of the position occupied by the pieces to be welded. This suggested the solution of a problem which has been sought for during the past 40 years, namely, the welding of rails in position on the track. Recently, these experiments have been taken up again, especially in America, with the aid of the electric current, using the Thomson-Houston process. The apparatus required is, however, very cumbersome and, moreover, very expensive, no less than some 200 horsepower being necessary. It seems that experiments in welding rails electrically, after having been tried in many places, have always been dropped because the process was too cumbersome, too expensive, and above all not always quite reliable.

Attempts were next made to weld rails in the method indicated above. The ends of two rails were pressed into close contact and fluid corundum poured over the junction, the latter having first been surrounded by a suitable mould (Fig. 2). After a few experiments, the welding was found to be successful, but there was still one main objection; only a portion of the molten mass was employed as a source of heat, and that portion the worst, for

the metal which gives up its heat more rapidly than the remainder of the melt was always left behind in the crucible. It was soon, however, seen that on pouring in the molten corundum, the portion which touched the cold rails immediately set and was not again liquefied by the molten corundum subsequently running over it. Experiments were then tried by pouring upon this rapidly-set corundum the metal in the crucible, which consisted chiefly of iron together with some manganese, and it was thus found that even this molten metal was incapable of perforating the crust of corundum after the latter had once set. Welds were, therefore, afterwards made by pouring the entire contents of the crucible, that is to say, both slag and metal, on the place to be welded. It was found that the metal settled down in the lowest portion of the mould, never coming into direct contact either with the rail or

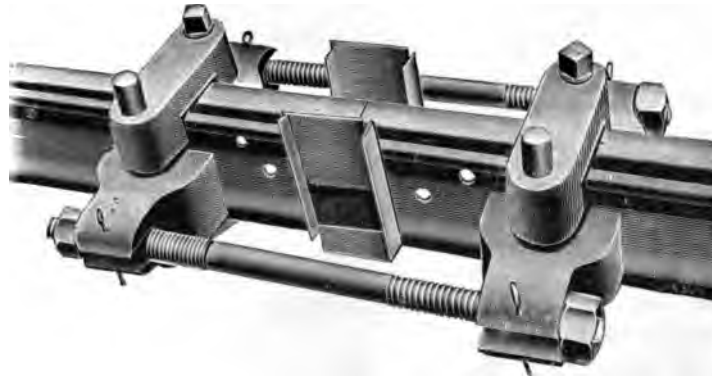

FIG. 2.—RAILS PREPARED FOR WELDING, WITH CLAMPS AND SHEET-IRON MOULD IN POSITION.

the sheet-iron forming the mould-case, so that, once cold, the iron mass could easily be removed from the welded part and from the inside of the mould.

By this process of pouring on the whole melt, a number of further advantages of very far-reaching importance have been obtained. Firstly, owing to the fact that the heat generated during a period of some minutes is generated in the crucible, where it is conserved (owing to the rapidity of the reaction), and is then transferred to the pieces to be welded within a few seconds, a great—say a 60 fold—concentration of energy is obtained, as no loss of heat to speak of takes place during the reaction in the crucible. Secondly, since the necessary quantity of heat can be weighed up in the form of an empirically determinable quantity

of thermite, a method of welding has for the first time been devised in which the practised eye of the welder is not the measure of the heat to be given to the metal to be welded. The consequence is that such aluminothermic welding can easily be executed by workmen, even inexperienced men, and that specially trained men are not required for it. Thirdly, as this method of pouring involves the immediate covering of the spot to be welded, welding takes place with complete exclusion of air, so that atmospheric oxygen can have no action upon the parts which are being welded. The surfaces remain therefore unaltered beneath their protecting cover of corundum. This is of capital importance, and is an explanation of the excellent results that have been obtained by this method. Fourthly, slow cooling of the welded part can be obtained, inasmuch as the melt, after it has set, need only be removed whenever desired from the spot that has been welded. Finally, since the entire contents of the crucible, that is to say corundum as well as metal, are employed as a source of heat, welding by this process can compete as regards cost with any substantially made form of joint; and this is true, not only of rails, but, as has been shown by calculation, of iron beams in general.

The following examples show the application of this process to the welding of wrought-iron pipes, in both vertical and horizontal positions. The arrangement will be quite intelligible from what has been said. By means of suitable clamps, the clean-cut and squared ends of the pipes are firmly drawn together (Fig. 3). A small sheet-iron casing of suitable size (Figs. 4 and 5), jacketed externally with moist sand, which again is kept in place by a box surrounding it, is used for enclosing uniformly the place to be welded (Fig. 6). The thermite is prepared in a crucible, and immediately poured into the mould. As soon as the welding temperature has been reached, it is necessary to tighten up the screws by one turn, in order to obtain the requisite pressure for welding. A 3 inches pipe, 0·16 inch in thickness, can be welded with 5 pounds of thermite. The distance of the sheet-iron mould from the outside of the pipe is 0·72 inch, and the length of the mould is 3·20 inches. A welding temperature is reached 1½ minutes after the melt is poured in (Fig. 7). A table has been drawn up which shows the dimensions of the mould and the quantity of thermite, etc., to be employed to weld tubes of the

more usual dimensions.* As may be seen, this method of welding tubes may be employed in all positions of the tube, and whilst the tube is being laid, and can therefore replace flanged joints.

The advantages of welds as compared with flanged joints are so obvious as scarcely to need mention. The strength of these welds is exceedingly high, and equal to the greatest demands that can be made upon them (Fig. 8). Repeated experiments have

FIG. 3.—TWO INCHES PIPES WITH TENSION-CLAMPS ATTACHED.

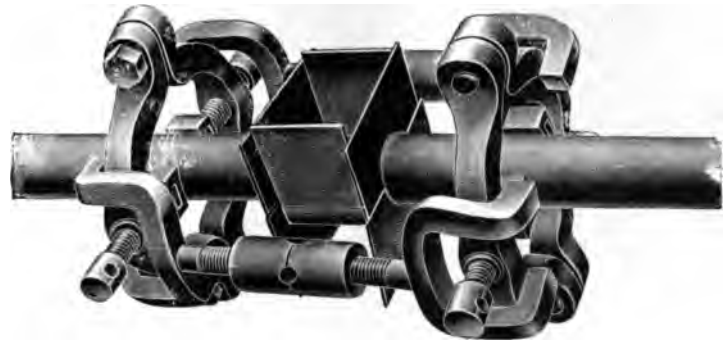

FIG. 4.—HORIZONTAL PIPES WITH SHEET-IRON MOULD IN POSITION.

shown that such welded tubes can resist a pressure of 400 atmospheres, and even more. On attempting to break the welded tube, it has been shown that the latter splits lengthways before it breaks across the weld (Fig. 9); and such welded tubes can be bent at the weld to any desired radius (Fig. 10).

* It has recently been found possible to manufacture thermite possessing greater calorific power than that possessed by the material formerly produced. As about 30 per cent. less of this material is required, and the price remains the same, there is a great reduction in the cost of welding.

The cost of welding tubes is considerably less than that of a flanged joint or a good coupling, while it must not be forgotten that flanged joints can only resist a pressure of 15 to 30 atmospheres. It may be mentioned that the welding of two tubes of 2 inches inside diameter costs from 2s. to 4s., according as the thickness ranges from 0·10 to 0·24 inch, the above prices including crucible, mould and labour. An ordinary substantial flanged joint for this size of pipe could not be obtained for less than 5s. or 7s., while flanged joints that can resist a pressure of 100 to 200 atmospheres are much more costly. As against all these advantages, there is only one disadvantage that must be noticed, namely, the difficulty of cutting a welded joint, compared with the ease with which a flanged joint can be taken apart. It is therefore evident at the outset that pipe-lines which are again shortly to be removed or altered should not be welded. The number of such pipe-lines is, however, very small compared with those which it is not intended to alter within a reasonable period. On the other hand, such pipe-lines which it is not intended to alter when they are laid down, need not necessarily have all their joints welded, but here and there a more easily broken joint could be put in, so that it is easy to arrange for branch lines at any time. It will, however, occur to every practical man that the use of flanges need only be a very limited one, as the sawing through of a tube is not a laborious operation, and causes little more difficulty than the loosening of an old and rusted joint, which can only be performed by means of hammer and chisel.

FIG. 5.—MOULD FOR WELDING VERTICAL IRON PIPES.

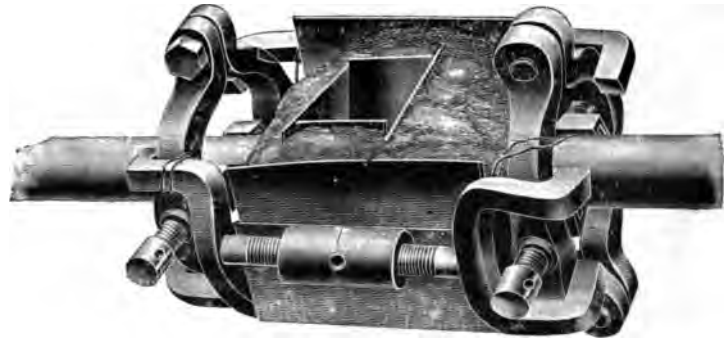

FIG. 6.—PIPE READY FOR POURING ON THERMITE.

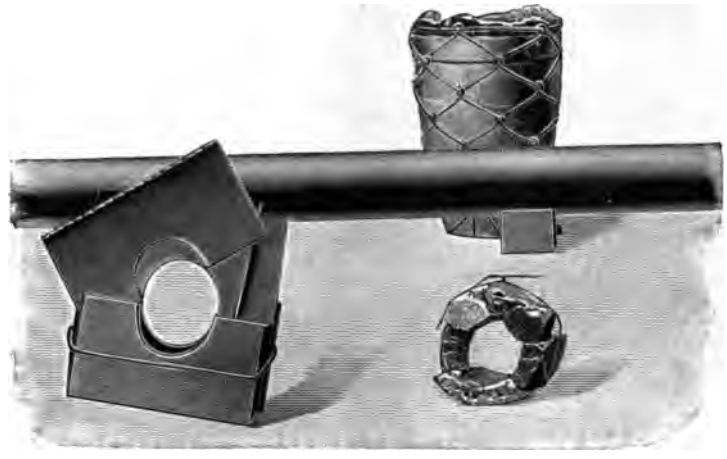

FIG. 7.—WELDED PIPE, CRUCIBLE, MOULD, AND SOLIDIFIED MELT AFTER REMOVAL.

FIG. 8.—TENSION TEST-PIECE CUT OUT OF WELDED PIPE. THE ETCHED PORTION IN THE CENTRE SHOWS THE WELD. STRENGTH, 52,300 POUNDS PER SQUARE INCH; EXTENSION, 11·5 PER CENT. STRENGTH OF THE UNWELDED MATERIAL, 54,750 POUNDS PER SQUARE INCH; EXTENSION, 15 PER CENT.

Finally, it may be noticed that a T piece may be inserted by this new process at any required spot, without the necessity of taking apart the pipe in question.

FIG. 9.—PIPES WHICH SPLIT LONGITUDINALLY ON BEING FLATTENED, WHILE THE TRANSVERSE WELD IN THE MIDDLE REMAINED INTACT.

FIG. 10.—PIPE BENT AT THE WELD.

The advantages of this new process over those hitherto known for uniting wrought-iron pipes may be summarized as follows:—(1) It can be applied to pipes in all positions and to all lengths. (2) Its application requires neither machinery, nor cumbersome apparatus, nor skilled workmen. (3) A weld is essentially cheaper than a flanged joint or coupling. (4) There are no maintenance-expenses, as the joint requires no packing of any kind. These advantages are most marked where high pressures are employed.

As regards iron or steel rails, the advantages presented by welding as against joining by fish-plates are various. In the first place, there are advantages of construction. As no bolts are employed, the rails form a continuous and uniform bar. This enables the rail to be set close up to the pavement in the case of street-railways, which is a difficult matter where fish-plates are employed. Further, carriages travel more smoothly over the

junction. There is consequently a great saving in the rolling stock; even the strongest joints are unable to couple the ends of the rails so firmly together that in time the bolts do not work loose, thus producing a loosening of the entire system, which obviously becomes continuously worse in the course of use. The wheels commence to strike against the ends of the rails, and thus these spots wear away with undue rapidity. In order to prevent this loosening of the fish-plates, the bolts must be tightened from time to time, the rails must be packed, and the fish-plates, bolts, etc., require renewing. These costs are still greater in the case of street-railways, because they are combined with the necessity

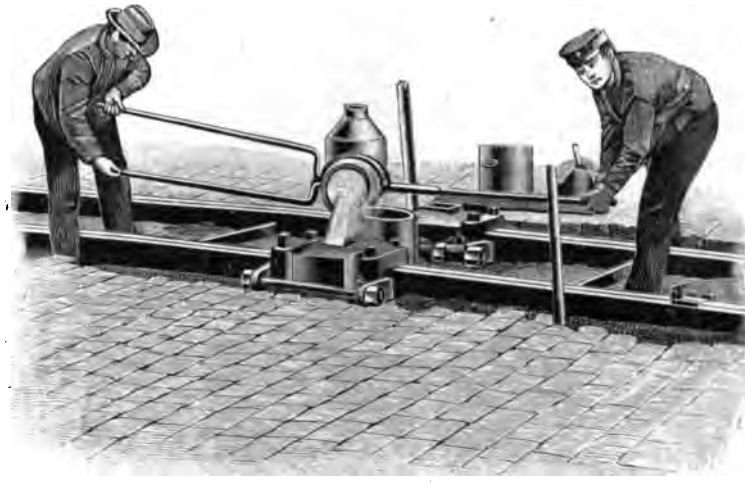

FIG. 11.—WELDING RAILS IN POSITION IN BRUNSWICK, FRIEDRICH-WILHELM-PLATZ, MAY, 1900.

of lifting the pavement. These disadvantages disappear entirely when the rails are welded, as such a joint is no longer liable to work loose. In Essen, two sections of such welded rails have been in constant use throughout a period of 1 year, and a number of municipal corporations at home and abroad have decided to have a portion of their rails welded. A few months ago, two long sections of the electric railway were welded in Brunswick (Fig. 11); and in Berlin, Dresden, Plauen, etc., the rails of the electric tramways have been welded together by this process. According to the statements of tramway companies, such welds as

those herein described have rendered excellent service. The welding has been done rapidly and without a hitch, the welded parts can scarcely be recognized, and are not perceptible in travelling over them. As the rails of electric railways are buried in the earth or in the pavement, change of temperature (involving extension and contraction of the rails) does not affect them as it does rails of ordinary railways. The former can therefore be welded together in long sections, without giving rise to any bending in the summer or tearing in the winter, and this statement does not depend only on calculation, but has been proved by direct experiment. This proof was obtained in the summer of 1899 by cooling a length of 328 feet of a welded line during several hours by means of a mixture of ice and salt. This simple and cheap process of welding greatly interests also the great railway companies. In the case of these latter, it will indeed not be possible immediately to weld up the entire length of rails, as will undoubtedly be done in the case of rails embedded in street pavements. It is known that a great number of street tramway companies, for instance, the Grosse Berliner Strassenbahnen, lay all their rails without leaving any space at the joints. This latter company has even had all spaces that may exist filled with steel wedges.

How far rails lying on the surface of the ground may be welded cannot be answered without further experiments. The fact that rails are now often laid in 60 feet lengths, while formerly the maximum length was 20 feet, without there being any need for making the spaces between the rails three times as great as it formerly was, suggests the assumption that the lengths of rails may be carried even further without there being any need to make the spaces inconveniently great. Above all, there is scarcely any technical reason for hesitating to weld together 20 or 30 feet lengths of rails in twos or threes, and great advantages will be obtained by doing so. The welding of greater lengths of such rails must necessarily depend upon the way in which the rails are secured to the sleepers, on the nature of the ground, the character of the trains, of the climate, of the curves, etc. The opinion is also generally held by technical men that all rails laid in tunnels can be welded, thus producing a very considerable advantage, as the objectionable permanent-way works in tunnels could thus be reduced to a minimum. In such tunnels, the temperature is very uniform,

and experiments have shown that rails in tunnels are practically protected from alterations of length due to change of temperature.

Another important point speaks in favour of the welding of tram-lines. Because, in the case of electrical street railways a good electric contact of the rails is of especial importance. The copper connectors that have been almost universally adopted up to the present for bridging each junction solve the difficulty but imperfectly, as it is well known that copper and iron buried in moist earth produce galvanic currents. Considerable damage is done by the wandering currents due to such action, and in order to reduce this to a minimum the welding together of the rails is

FIG. 12.—REPAIRING A DEFECTIVE STEEL-CASTING.

recommended as the most effective method. Apart, however, from these advantages, a welded tram-line is much cheaper in maintenance, as also in first cost, than a line joined with fish-plates and copper conductors. It is calculated that the economy would amount to about 20 per cent. of the capital, if the cost of maintenance be capitalized, in the case of a welded rail as against fish-plates and copper conductors: even though the latter are only put down as costing 13s. 4d. and the welds at 20s.

A further application of this process, of special importance to the metallurgist, may be mentioned. It has been found that iron

separates out almost completely from a mixture of oxide of iron with aluminium, and that such iron is free from aluminium, provided that a certain excess of iron oxide is employed. If sufficiently pure materials are employed, a very pure soft malleable iron is produced which approximates in composition to the soft so-called Swedish charcoal iron. To this iron reduced by aluminium, all the constituents may be added that are considered necessary, and it may thus receive all the properties of a steel. For example, carbon or carbonaceous material may be added to the thermite in order to carburize the metal, while for example 1 per cent. of man-

FIG. 13.—SECTION OF TOOTHED WHEEL (4 FEET IN DIAMETER AND 15 INCHES WIDE) WITH BROKEN TEETH. WELD PARTLY MACHINED, PARTLY UNMACHINED.

ganese, 4 per cent. of nickel, etc., may also be alloyed with it. The production of such thermite steel of definite and desired composition requires practical experience, as a large number of circumstances have to be taken into account which can only be learned by practice.

The possibility of preparing iron and steel of the most varying composition in any desired quantity rapidly and simply at a temperature of about 3,000° Cent. has suggested a process for the repair of defective or worn-out steel castings or iron forgings. For that purpose, iron, heated far above its melting-point, has the property, when poured for example into a hollow in an iron block,

of raising the walls of the cavity so rapidly to the welding point that the metal poured in is intimately united to it.

The process has special advantages where the hitherto used electrical methods are no longer available—that is to say especially in repairing large faulty places (Fig. 12). Excellent results have also been obtained with smaller repairs. Naturally such iron may also be employed to strengthen up a casting, to repair broken teeth of spur-wheels (Fig. 13), etc.

In all cases, tests of every kind have shown that the castings thus produced are equal to all the demands that may be made upon the metal, provided only that the necessary conditions, which are, however, thoroughly simple, are always properly fulfilled.

The softening of armour-plates is performed by pouring upon the spot to be softened a certain quantity of fluid thermite from a crucible. Under the action of this intense heat upon one spot, and the slow cooling following upon it, which is simply produced by allowing the molten mass to remain for some time after its solidification, the desired large or small spot is sufficiently softened, this being of importance when it is required to bore holes into the plate. Up to the present, such softening has always been done by means of a small oxy-hydrogen blow-pipe, with which method, however, the operation was very slow.

A large number of further applications in widely differing branches of industry are now being introduced, and others are under consideration, so that the hope is justifiable that alumino-thermite may in a brief period become an important and perhaps indispensable auxiliary in many branches of technology.

Mr. SYDNEY F. WALKER read a paper on "Alternating Currents and their Possible Application to Mining Operations," which will be printed in a succeeding volume of the *Transactions*.

UNDERGROUND GEOLOGY IN THE SOUTH-EAST OF ENGLAND.*

By W. WHITAKER, B.A., F.R.S.

After alluding to the progress of geology, the author specially discussed "Underground Geology in the South-east of England," as follows:—

Many years ago our knowledge of what was to be found deep underground was almost limited to mining districts, whether metalliferous or coal-bearing, and even in such cases the recording of details was too often neglected, the value of such details not being at that time understood. The great advantage of possessing careful records of the beds passed through in shafts or borings has now been recognized for some time, especially in such cases as trials for proving the underground extension of Coal-measures beneath not only Permian and Triassic rocks, but also beneath still higher formations, as, for instance, in part of the Bristol coal-field.

In this work it is important to record details of the rocks above the Coal-measures, so as to have some grounds for estimating the thickness of those rocks in neighbouring localities. Thus the widening of the areas over which coal may be worked leads to further knowledge of overlying formations. Moreover, we also gain information as to the range of the various seams of coal and of the changes which those seams undergo, and are enabled to correlate sections at some distance.

The Vertical Sections and various Memoirs of the Geological Survey supply much information of this sort; but the greatest collection of such details is the fine set of six volumes published by the North of England Institute of Mining and Mechanical Engineers, embodying an account of over 2,350 sections.†

* Part of the Anniversary Address by the President. Reprinted, in third person, by permission of the Council of the Geological Society from the *Quarterly Journal of the Geological Society*, 1900, vol. lvi., pages lxx.-lxxxvii.

† *An Account of the Strata of Northumberland and Durham as proved by Borings and Sinkings*, 1878-1897.

The author does not, however, mean to pursue the subject of the search for coal, in itself almost too wide for a single address; but to draw your attention to another source of information of a more widespread kind. The parts where coal can be worked are naturally limited, though often extensive; but the need for water is universal, and over a great extent of country water has to be got, partly or wholly, from underground sources by means of wells and borings. These, with trial-borings made for various purposes, are mostly the sole available evidence of the underground extension of various formations.

Even in this subject it will be well to fix a topographical limit. Much information has been collected dealing with various parts of our country, especially as regards Triassic and Cretaceous rocks; but the writer proposed to limit his remarks on the whole to a large district over which he has worked, which may be roughly named the south-east of England, and gives, he thinks, the best illustration of the advance of this kind of knowledge within his own time.

Underground Geology in the South-east of England.

In bygone years, many notices of wells or of groups of wells were certainly published; but seldom with details, in most cases only the thickness of formations being stated or merely the depth to the Chalk. Sometimes, moreover, the figures given have proved to be wrong.

So far as the author knows, the remarkable work of the Rev. J. Townsend, practically the first general account of the geology of England, is the first case in which reference is made to sets of wells as proving the thickness of formations, in this case of the Chalk, of the Great Oolite, and of the Inferior Oolite.*

Afterwards the names of Mitchell, Mylne, Clutterbuck and Clarke are prominent among our contributors to underground knowledge, to be followed a little later by that of Prestwich. But, as a rule, their work, as above noted, did not give much detail; and it was not until 1854, when the author was a student under Morris, that the first goodly collection of well-sections, with trustworthy details and modern classification of the Tertiary formations, was

* *The Character of Moses established for Veracity as an Historian, recording Events from the Creation to the Deluge*, Bath, 1813, pages 123, 124, 129 and 130. (Nearly the whole of the book refers to geology rather than to Moses.)

published, in Prestwich's great paper "The Woolwich and Reading Series."*

In this paper, one which will always rank among our classics, fifty-five wells in the London Basin are described, most of them in detail. It is perhaps strange that the value of such a collection of sections, many carried to a great depth and through beds which do not crop out at the surface within considerable distances, was not at once seen. Such, however, seems to have been the case, and in preparing a Geological Survey Memoir descriptive of a tract that contained many of the sites of these wells, published ten years later, the author was content to give a mere abstract of some of these sections, instead of reproducing them in full, an error of judgment that has been corrected in later Memoirs.

The collection and publication of such matters of detail is pre-eminently the work of the Geological Survey, whose Memoirs, as a rule, are intended to be works of reference rather than light literature; and during nearly 30 years that Survey has published records of many hundreds, one may say some thousands, of sections of wells and borings, chiefly in the tract with which we are now concerned, but also in other districts. Smaller, but goodly, contributions for various parts of England are to be found in the Reports of the Underground Water Committee of the British Association and in the publications of many societies and by several authors.

The detailed knowledge thus gained, as to South-eastern England, has been fruitful in general results, of which the following seem to be the more notable:—

1. In proving the thickness of the Drift at a large number of places, and in showing that this thickness is often greater, sometimes far greater, than had been expected, even to the extent of reaching to below sea-level far inland.

2. In proving that some of the Crag-beds are of much greater thickness underground than we had reason to think, from our knowledge of them where their whole thickness is seen at the surface and is small.

3. In giving us a much better idea of the extent of the Eocene Tertiaries underground than we had before, in parts where they are hidden by wide or thick coverings of Drift or of Pliocene. Over large tracts in East Anglia that are represented as Chalk on

* *Quarterly Journal of the Geological Society*, vol. x., pages 94 to 97, 105, and 139 to 154.

old geological maps, we now know that the Drift, etc. is next underlain by older Tertiary strata.

4. In proving the depth to the Chalk in very many places: so much indeed in the immediate neighbourhood of London that it would be a fairly easy, though laborious task, to lay down on a map contour-lines of the depth to the Chalk, referred of course to Ordnance-datum level, a work that the author hoped may be undertaken ere long.

With these four subjects goes of course a great addition to our knowledge of the various local conditions of the formations passed through, as well as of their varying thicknesses.

So far reference has been made to published information only; but in continuing these remarks the author would also occasionally have to make some use of unpublished material, whether in the hands of Prof. Boyd Dawkins and of Mr. Etheridge, both of whom the author had to thank for information, or in his own. Of course, such unpublished notes are used, subject to correction.

That the Chalk everywhere underlies the Tertiary of the London and Hampshire Basins is a sort of axiom, long taken for granted by all geologists; but it is nevertheless satisfactory to be able practically to prove it, from the fact that whenever a hole is dug deep enough Chalk is found: for unbelievers in matters geological are not yet extinct. The immense mass of accumulated evidence has long been enough to convince any reasonable being, and we can afford to ignore unreasonable ones, for there are more than 800 wells and borings that pass through Eocene beds to the Chalk in the London Basin.

It is different, however, when we come to the question of what next underlies the Chalk deep underground; and it is to this, the underground extension of formations older than the Chalk, that the author particularly wished to draw attention, making use not only of borings for water, but of others of a more experimental kind. He hoped to be forgiven for omitting references to the many authors who have contributed to our knowledge.

While we see, from our geological maps, that the Chalk occurs everywhere round the Tertiary beds of the two Basins, and mostly with a broad outcrop, it is not quite the same with the underlying Cretaceous divisions. Though the Upper Greensand and the Gault are now in a fair way of being taken as parts of one formation, which it is proposed to call Selbornian, yet in the present case there is some convenience in dealing with the two separately, not using

the new classification until the Geological Survey Monograph on the Upper Cretaceous formations is in our hands.* First let us deal with the London Basin, including therein the Chalk as well as the Tertiary, and also taking in part of the Wealden tract.

The London Basin and Weald.

The Upper Greensand being, as a rule, comparatively thin at its outcrop and of somewhat varying character, one is not surprised to find it absent at the surface over considerable parts of the bordering Cretaceous tract. The Gault, on the other hand, is a practically persistent mass of clay, and the only part where this clay does not occur at the surface (where lower beds crop out from beneath the Chalk of the London Basin) is far north, in north-western Norfolk, and there only the thin Red Chalk comes between the White Chalk and the Carstone of the Lower Greensand.

The Lower Greensand, in general a fairly thick formation, has a continuous outcrop round the district of the Weald, except perhaps in the far east of Sussex, where it is certainly thin and apparently sometimes absent. On the northern side of the London Basin it is occasionally wanting at the surface, owing to overlap of the Gault.

The Wealden beds, from their freshwater and estuarine nature, are more local, and though very thick on the south, in the tract from which the name is taken, are almost confined to that part, the occurrence on the north being insignificant. No one, therefore, expected to find their underground range very great.

The Chalk.

The great number of wells reaching the Chalk through Tertiary beds has been noticed, and many of these go to a considerable depth in the Chalk; but it is rather rare for a boring that starts in the Tertiary beds to pass through the Upper Chalk (the thickest division) into the Middle Chalk, and it is still more rare to find a boring that reaches down from the top of the Chalk to its base. Prestwich was the first to record any such borings, those at Kentish Town and at Harwich, and for many years these alone held the field.

* *The Cretaceous Rocks of Britain*, vol. i.: "The Gault and Upper Greensand of England," by Mr. A. J. Jukes-Browne, with contributions by Mr. William Hill. Chapter xxvi. (pages 367 to 377) treats of Subterranean Extension of the Gault and Upper Greensand. This monograph has been published since this address was written.

In the great tract of the London Basin there are only fifteen places where such borings have been made; but at eight others nearly the whole thickness of the Chalk has been pierced, the sites being either at no great distance from where the Tertiary beds come on, or so high on the Chalk that no great thickness of it can have been removed. Besides these, others, beginning somewhat lower down in the Chalk, have yet pierced a considerable thickness of it.

The first new fact that we learn from these deep borings is the thickness of the Chalk; and this at its lowest is over 620 feet (at Streatham), while in the highest case it reaches to more than 1,140 feet; and this latter is at Norwich, where the top of the formation is absent: so that we have probably a difference at the rate of 2 to 1. It is shown, too, from several borings that the least thickness is in the middle part of the Basin and in the neighbourhood of London, while the greatest is in the north-east.

As regards the divisions of the Chalk not much has been learnt, but enough to indicate that all three, Upper, Middle and Lower, extend underground, as might be expected.

The Upper Greensand.

Coming to the formations beneath the Chalk, except at sites near their outcrop there is no evidence of underground extension westward of Winkfield, near Windsor; and so, for the present, our view must be limited to that part of the London Basin which lies east of a north-and-south line from Wendover to Aldershot. There can be little doubt, however, that Upper Greensand and Gault occur throughout the tract to the west.

Eastward from Winkfield, where it is 31 feet thick, the Upper Greensand occurs in all the deep borings along the broad valley of the Thames, at Richmond, and in London to Crossness, never exceeding the thickness at Winkfield, but irregularly decreasing to 12 feet at Crossness and to 10 feet at Shoreham, in the valley of the Darent.

Beyond this eastward, in Kent, it has not again been found in any of the twelve or more borings that have been carried deep enough to prove it. This agrees with the thinning at the outcrop, no Upper Greensand that could be mapped having been found beyond a few miles eastward of the Darent, except for a short distance near Folkestone.

North of the valley of the Thames it is absent at Bushey, near Watford, which is practically on the line between the thinning-out on the southern outcrop, at Kemsing, and the point beyond which Upper Greensand cannot be mapped on the northerly outcrop near Tring, though it is again seen a little near Dunstable.

So far, therefore, the underground evidence agrees remarkably well with that obtained aboveground. But north of London the conditions are different, the Upper Greensand extending underground in renewed force up the valley of the Lea, being 44 feet thick at Cheshunt and 40 feet at Ware, quite a respectable thickness for this division so far east. It also occurs at Loughton, in Essex, where it is 30 feet thick, whence one may infer that from London a northerly extension or bay of Upper Greensand juts out.

North of the Thames eastward of the above-mentioned localities there is but little information, and what there is comes from a long way off. An old manuscript description of a boring made at Coombs, near Stowmarket, Suffolk, in 1855, says that Gault and Greensand alternately, to the thickness of 21 feet, were found at the bottom, while a printed account (of 1860) definitely mentions 10 feet of Upper Greensand between the Chalk and Gault; but this is not enough to warrant one in making sure of the first, as it is not uncommon for the glauconitic base of the Chalk Marl to be called Upper Greensand, and no lithological description is given.

At Harwich, again, occurs Gault mixed with Greensand, for 22 feet, which is no more satisfactory, and at Norwich we are still left in doubt. On the other hand, there are three borings in which no Upper Greensand was found, at Weeley (south-west of Harwich), at Stutton (west of Harwich), and at Culford (north of Bury St. Edmunds), and the clear evidence of these outweighs the doubtful evidence of the borings at Coombs and Harwich.

Nor is there in the northern part of Norfolk any Upper Greensand, so far as is known; thus, on the whole, it may be said that under East Anglia, with the exception of the western margin of Essex, there is probably none of it, or but a little here and there. That so thin a division should extend so far as it does is perhaps more to be wondered at, than that it should be absent over a large extent of country.

The Gault.

The Gault is the only formation below the Chalk that has any claim to the virtue of constancy in underground matters. In every

one of the deep borings has it been found, and except in the far north-western part of the Norfolk Cretaceous tract, there is every reason to expect that Gault will be found in any new boring that goes deep enough. With constancy of occurrence, however, there is considerable vacillation in the matter of thickness, though not locally, only as regards places far apart. With the question of thickness alone, therefore, are we concerned.

The greatest thickness of Gault known (over 340 feet), in the district under consideration, is in the deep boring at Caterham in eastern Surrey, near the outcrop, which outcrop seems to have been made a little too narrow here on the Geological Survey map, the uppermost part of the Gault having apparently been classed with the Upper Greensand, into which, indeed, it passes up.

At Winkfield, on the west, is the next greatest thickness (264 feet), decreasing thence eastward, along the valley of the Thames, to 201 feet at Richmond; and to between 130 and 188 feet in and near London. There must be a rapid thinning northward from Caterham.

Easterly thinning from Caterham is also fairly marked, there being something more than 237 feet at Sundridge, where the very top has been removed, and at Shoreham 226 feet.

The many borings in the valley of the Medway show a thickness decreasing from 234 feet on the south, where the river enters the Chalk tract, to 192 feet at and below Rochester.

Pursuing an easterly course there is no certain evidence for some distance: but the Gault ultimately thins in that direction, for at Ottinge, in the parish of Elham, it is 127 feet thick; at Ropersole (? in Barham) between Canterbury and Dover, 119 feet; and on the coast at Folkestone, about 100 feet. Although north-east of the last-mentioned place, in the two borings near Dover, it reaches a higher thickness (121 and then 144 feet), thence northward it decreases to only 63 feet at Margate.

Along or near the northern outcrop, the thickness is over 215 feet at Long Marston, near Tring, where the top beds have been removed, and 214 feet at Hitchin; but this decreases underground towards London, the thickness at Ware being 163 feet.

The multitude of borings in the neighbourhood of Cambridge show a decided north-easterly thinning, the thickness varying generally from 175 to nearly 110 feet, with considerably more in a single case and considerably less in another. Farther northward

the thinning continues to 90 feet at Soham, 56 feet at Stoke Ferry, and 20 feet at Narborough.

Leaving out of account the boring at Saffron Walden, of which there is no trustworthy record, but which, judging by its depth, must pass through the Gault, there are four deep borings in northern Essex and in Suffolk that certainly do so (at Weeley, Harwich, Stutton and Culford), and in these the thickness varies from 49 to 76 feet, while in the one boring in northern Norfolk, at Holkham, it is but 10 feet. This last shows, however, that underground the Gault Clay extends northward to the coast, though at the outcrop it thins out several miles southward thereof, where its place is taken by the Red Chalk. It is noteworthy that, at Holkham both formations occur, and that this is the only case of the occurrence of Red Chalk over Gault.

We may take it, therefore, as almost proved that while the Gault Clay is continuous under the London Basin, except in the north-western corner of Norfolk, there is a general but irregular thinning eastward from Winkfield, accompanied by a northerly thinning, from the outcrop in eastern Surrey and in Kent. It is to be noted, too, that this is also the case with the Selbornian as a whole, but more decidedly, as the Upper Greensand is absent eastward and north-eastward.

The Lower Greensand.

Putting out of consideration the great number of borings in the neighbourhood of Cambridge (made for the purpose of obtaining water from the Lower Greensand), almost all of which are either on the Chalk Marl or on the Gault, and sundry other borings also near the outcrop in various parts, mostly, indeed, on the Gault, few borings reach this formation, and eight or nine only pierce it from top to bottom. Nevertheless, what is learnt of it is of more interest than what has been learnt of the Gault, for in these matters change is more charming than constancy, and the underground thinning of the Lower Greensand is a question that has been often before geologists.

There is sometimes evidence of great thinning at or near the outcrop; thus a boring at Shillingford, near Wallingford, after piercing 144 feet of Gault, proved a thickness of only 25 feet of Lower Greensand, passing then into Kimeridge Clay and thereafter through Corallian beds to Oxford Clay.

The presence of this formation at the bottom of the Winkfield boring leads one to infer that this occurrence of Lower Greensand deep underground will be found to continue to the southern outcrop, where the formation shows in force; but there is no evidence how far northward of Winkfield this continuity may reach. It may be to the outcrops to the north-west or to the north. It may be, on the other hand, that there is a thinning out, as along the northern boundary of the Gault, from west-north-west to north.

Eastward, at Richmond, there is a thickness of only 10 feet, although at the outcrop, some 15 miles southward, there is a goodly mass. A little farther north probably no Lower Greensand would be found, for in other borings in or near London, from Streatham on the south to Ware on the north and to Crossness on the east, there is none, the Gault resting directly on some much older formation. One is led, however, to infer the presence of this division at Loughton, where the Gault is underlain by sand.

Never again on the north of the Thames do we get evidence of the underground occurrence of Lower Greensand in places far removed from the outcrop, until reaching Culford, in Suffolk, where a thickness of about 32 feet of beds has been classed with this formation, and on the far north at Holkham, where there are either 50 or 70 feet of it, accounts varying, and where the base may or may not have been reached. Eastward, however, from Culford the borings at Weeley, at Stutton, and at Harwich show that the Lower Greensand has thinned out.

South of the Thames, in Kent, though evidence of considerable thinning northward from the fairly broad outcrop is available, there is as yet no proof of the underground thinning-out of the Lower Greensand eastward of the Darent: all the borings that have gone deep enough having demonstrated the presence of this formation. Westward of the Darent its thinning-out is known from the Crossness boring.

Along the valley of the Medway, several borings have struck a good supply of water from the Lower Greensand, but in one alone, at Chatham, has it been pierced to its base, and proved to be only 41 feet thick. It certainly reaches some way farther north, to beyond Chattenden.

Farther eastward there is no evidence, except close to the outcrop, until reaching the valley of the Little Stour, at the higher part of which a boring at Ottinge, in the parish of Elham, starting

in the Lower Chalk, has proved that the Lower Greensand is more than 200 feet thick; while at Ropersole, some 5 miles north-east and at a greater depth, the thickness is only 72 feet.

Again, at the workings for coal south-west of Dover, 124 feet of beds have been assigned to this formation, less than the thickness at the outcrop at Folkestone; whereas at the Convict Prison north-east of the former town the thickness has fallen to 31 feet. Unexpectedly, however, a boring at Margate, many miles farther north, has passed through more than 70 feet of what is apparently Lower Greensand, without reaching the base.

In the foregoing notes no attempt has been made to deal with the various divisions of the Lower Greensand; it seems better to leave that branch of the subject until detailed descriptions of the Kentish borings from Mr. Etheridge and from Prof. Boyd Dawkins are published. Let it suffice to say now that the Hythe Beds seem the most apt to thin out. In like manner details of the Wealden, Jurassic, and other formations will be passed by.

The Wealden and Purbeck Beds.

We have seen how considerable is the rate of thinning of the Lower Greensand underground from its outcrop; but it is small as compared with that of the much thicker Wealden Beds, with which it is here convenient to associate the Purbeck. From the fact that there are but traces of the Wealden Beds on the north of the London Basin, with little also of the Purbeck Beds, it is evident that these formations must disappear somewhere under the middle part of the Basin.

But before noticing this thinning more attentively, let us give some passing consideration to what has been already learnt of late by works carried to some depth in the Wealden district itself. The chief result perhaps is that our estimates of the thickness of the various divisions have been shown to be often too small, taking Mr. W. Topley's admirable Survey Memoir on *The Geology of the Weald* as our standard, the maximum thicknesses therein assigned having been passed, and that not rarely. This, by the way, is a sign of the excellence of that memoir, for probably the general tendency of writers is to luxuriate in high figures: temperance is not always the easiest virtue.

Perhaps the most notable boring from this point of view is that at Penshurst, which, beginning low down in the series, in the

Ashdown Beds, has not passed through the Wealden-Purbeck series until reaching a depth of perhaps 1,500 feet. This boring, too, is an illustration of another point that has been brought out by various borings: that is, the frequent difficulty of fixing divisional planes in this great set of deposits, especially when dealing with specimens brought up from considerable depths.

The trial-boring at Pluckley is of much interest also. Starting in the Weald Clay, and some way from the top of that formation, it has proved a thickness of no less than 720 feet thereof, whereas the underlying Hastings Beds are only 195 feet thick. The writer believes that there is also some sign of Purbeck Beds in this boring.

Returning to the subject of the northerly thinning of the Wealden Beds as a whole, at Richmond there is no sign of them, although that boring is not 16 miles from the nearest outcrop of the Weald Clay. At Streatham and Crossness, it is the same, though the borings there are respectively only 14 and 18 miles from that outcrop. The like statement holds good too of Chatham, where the deep boring at the dockyard is about 13 miles from the main outcrop, but only about 8 from that of the Maidstone inlier.

In all the more northerly borings these beds are absent: indeed, so far as we know, it is only in eastern Kent that they reach to any great distance under the Chalk tract and are then but thinly represented:—less than 250 feet at Ottinge (some 5 miles from the outcrop); only 55 feet at Ropersole; and 94 feet at the Dover colliery.

At Hothfield, in the Lower Greensand tract west of Ashford, the thickness seems to be only about 600 feet; and at Brabourne, on the Gault east of the same town, about 200 feet less.

One fact, therefore, to be clearly learnt from the deep borings in Surrey and in Kent, is the rapid northerly thinning of the very thick Wealden-Purbeck Series.

The Jurassic Beds.

Up to this point formations that occur at the surface in the south-east of England, the district with which we are specially concerned, have been dealt with. We may now pass to beds not seen in that district.

Before any of the deep borings were made nothing was known as to what formations occurred beneath the Purbeck Beds of the

Wealden tract, and these were the oldest known beds in the district. The great experimental boring of the Sub-Wealden Exploration, in the parish of Mountfield, near Battle, carried on the downward series in eastern Sussex continuously through the Upper Jurassic, in great thickness, and well into the Middle Jurassic, ending in Oxford Clay at a depth of more than 1,900 feet.

For some time this remained the only evidence of Jurassic beds underground within a great distance, the earlier borings at Kentish Town and at Harwich having proved the absence of such beds far off north-west and north-north-east; but further evidence is now available.

As regards the Upper Jurassic division, the westernmost occurrence is at Penshurst, where the boring ends in Kimeridge Clay of considerable thickness at the depth of 1,867 feet. The most northerly evidence is at Ropersole, where there may be 10 feet of that clay, between Purbeck Beds and Corallian. The Pluckley boring ends, as yet, in a thick mass of Kimeridge Clay, at the depth of 1,397 feet. At Brabourne, there are some 250 feet of the Upper division (chiefly Kimeridge Clay, but with a little Portlandian). At Ottinge and at Dover, this division also occurs.

The Middle Jurassic division reaches farther northward, to Chatham, where Oxford Clay next underlies the Lower Greensand. At Brabourne, both Corallian and Oxfordian occur, with a total thickness of nearly 550 feet; at Ropersole, there is about 300 feet of those formations, and they are also found at Dover; but we have no sign of them yet farther westward or northward than the places named. Southward, in the Sub-Wealden boring, more than 220 feet of beds above the Oxford Clay have been classed as Corallian.

The Lower Jurassic division has a still wider range, occurring in two of the London borings (Meux's and Streatham) as well as at Richmond. North of London, all the evidence we have is that of absence, as also at Crossness, on the east; but the trial-borings for coal at Brabourne, at Ropersole, and near Dover prove the existence of Lower Jurassic beds farther east, to the thickness of 189, 164 and 156 feet respectively.

We see then that, in every boring in which Jurassic beds have been found, the Lower division is represented wherever the borings are deep enough to reach it, and that the same is the case for the Middle division in every boring that has pierced through the Upper. On the other hand, there is one case (Chatham) where the

Upper division is absent, the Middle occurring next beneath Lower Greensand, and there are three cases where the Lower division alone is present, next beneath the Gault, in and near London. Further, in one only of the London borings north of the Thames, and that the most southerly (Meux's), are Jurassic beds of any sort present on that side of the river, all the borings farther north that go deep enough showing nothing between the Cretaceous and very much older rocks.

This successive northerly thinning of the Upper, Middle and Lower Jurassic divisions seems to point to the connexion of the underground Jurassic beds with masses farther south, and not with those of the northern outcrop. But what may happen west of Richmond we know not.

The Lias and the Trias.

Of that thick and mostly clayey formation the Lias, no sure sign was forthcoming until the Brabourne boring some two years ago proved its presence in eastern Kent. Since then it has also been found at Ropersole.

The discovery seems to the author most interesting, nothing of the sort having been found in the twelve other borings that have gone deep enough, unless some of the beds in the Dover boring should be classed as Lias.

At Brabourne, there may be some Upper Lias, and certainly both the Middle and Lower divisions are represented, the total thickness being 172 feet. But at Ropersole, to the north-east, the formation is much thinner, consisting of only 3 feet of the Upper division and over 24 feet of the Middle, with none of the Lower.

With regard to the Trias, we were left in doubt for many years. At Kentish Town, Richmond, Streatham and Crossness, various red rocks were found at the bottom of the borings, but what their age is we know not. They may be Triassic or Old Red, or both, with stained Carboniferous thrown in; though the changing balance of evidence seems to have veered against the first conclusion. We could not then say that the Trias was represented underground in the south-east of England before the time of the Brabourne boring, deep down in which (from about 1,876 to 1,925 feet) there has been found a conglomerate associated with red-and-grey sandy marls. This conglomerate contains, among other things, pebbles of Carboniferous Limestone, and has much the aspect of the Dolo-

mitic Conglomerate of the west of England, which presumably it represents. The Brabourne boring has an additional interest from this unexpected find, the only one of the sort.

The Older Rocks.

We have now done with the Secondary formations, and come to the perhaps still more interesting question of the older rocks beneath.

Of the Permian there is as yet no evidence, of the Carboniferous not much. The slaty rock at the base of the Harwich boring has hitherto been classed as of Lower Carboniferous age; but later evidence, from the neighbouring borings of Stutton and Weeley, and from Culford, the next nearest, has led some geologists to doubt this and to think that this rock may be much older. One has been, somewhat reluctantly, forced to the conclusion that all the bottom-rock in those three more recent borings is pre-Carboniferous, and there is some family likeness in all four cases, as perhaps you may some day hear in more detail.

Beyond the district to which the author specially alluded, Coal-measures have been found deep underground in the Jurassic district at Burford in Oxfordshire. At and near Northampton, Carboniferous Limestone was found in the town next beneath beds of doubtful age, at 527 feet below Ordnance-datum level; while at Gayton the same formation, thinly covered by Trias, comes up to 417 feet below Ordnance-datum level, being soon itself underlain by beds that may belong to the Old Red Sandstone; and at Orton a quartz-felsite was found only 341 feet below Ordnance-datum level. Of the bottom-rock in the Bletchley boring, farther south, one cannot speak with certainty.

Putting the Harwich boring aside, the first proof of the existence of Carboniferous rocks in south-eastern England was furnished by the trial-boring near Dover, which has passed through more than 1,000 feet of Coal-measures. The Ropersole boring has lately reached the same formation, and these two are the only decided evidence of Carboniferous rocks that we possess.

At Brabourne, the boring ends in a dark grey rock, with a dip of 60 degrees: what it may be is unrevealed. Mr. Etheridge simply says "not Carboniferous," Prof. Boyd Dawkins takes it to be Devonian, while the writer feels inclined to allow it to be anything

from Carboniferous to Silurian; but he has seen so little of it that this opinion is of small value.

As in the west of England, the Dolomitic Conglomerate occurs fringing an outcrop of Carboniferous Limestone, so may we expect it to occur in the east, as Prof. Boyd Dawkins has suggested; but on what side of Brabourne that is likely to happen is not certain. In this particular again the boring there is of high interest. That at Ottinge, being practically midway between this and Ropersole, would be likely to yield information of importance, and the writer agrees with Prof. Boyd Dawkins in regretting that it has been given up without passing through the Jurassic beds.

Descending in the geological scale, we at the same time have proof of still older rocks and of the absence of Carboniferous rocks at various places north of the Thames—and, if we allow that the doubtful red rocks are more likely to be of Old Red than of New Red age, in others south of the Thames also. There is no need to deal in detail with these older rocks, as most of them have been discussed at length in publications with which members are familiar, while the oldest (apparently) will have to be noticed in some paper to come.

Rocks of undoubted Devonian age have been found in two places only, in London (at Meux's) and at Cheshunt; while undoubted Silurian occurs farther north, at Ware, and presumable Silurian or still older rock far to the north-east, at Culford, Stutton, Weeley, and perhaps Harwich. In most of these cases, moreover, there is no sign of any newer rock until we reach the Gault. At Culford only very little Lower Greensand occurs, and at Meux's only a little Jurassic.

When we examine the position of the various older rocks as regards their relation one to the other, and the height which they reach, we find firstly that, as a rule, older and older formations rise in succession northward, so as to come next beneath the Secondary beds, and no boring so far has passed into more than one of these older rocks. Secondly, it is, as a rule, the oldest rocks that reach the highest levels underground, at Culford and at Ware, while the newest (Carboniferous) are at the lowest levels near Dover, leaving out of question the doubtful beds.

That this arrangement is universal, of course, one has no right to expect: there must be folds and faults, giving rise to troughs or basins, though as yet no proof of such has been brought forward.

So far as we have gone, therefore, a structure usual among old hill-ranges has been found, the older beds rising to the higher levels. It seems indeed that there lie beneath us the eroded remains of such a range, the sides of which were laved successively by Jurassic and by Cretaceous seas; but this old range apparently was not wholly submerged until the time of the Gault. Nor is there yet any evidence of a Gault shore: no conglomerate has yet been found at the base of the Gault, no pebble of the older rocks in the Gault, that formation showing in every boring its usual clayey character, which points to tranquil deposition.

Hampshire Basin.

The important subject to which your attention has been drawn is one that has arisen within the writer's own time, and that in and around one of the best known geological districts in the world, the London Basin. Our knowledge of the underground structure of this large tract has been vastly advanced.

We are also considerably wiser with regard to the great Wealden district to the south, including therein the outcrop of all formations below the Chalk. But when we go farther southward and westward to that other large tract known as the Hampshire Basin, including the Chalk again (and extending over parts of other counties than that from which the name is taken), our increased knowledge is less and goes down to a less geological depth.

We have certainly learnt much as to the thickness of various divisions of the Tertiary, both in Sussex and in Hampshire, and also of their underground extension, especially under the far-spreading mantle of Drift that reaches for some miles inland from the coast in great part of the former county, as shown on the new series of Geological Survey maps. The old series of maps indeed must often have been mere guesses in this matter, no evidence having been then obtained over the vast flat surface of the Drift tract.

We have, of course, at the same time learnt something of the depth to the Chalk, through the Eocene Tertiaries; but only by means of some 22 wells and borings in Sussex and as many in Hampshire. This small total of 44 wells is not an eighteenth of that in the London Basin.

As to the thickness of the Chalk under the Tertiary in the Hampshire Basin, this was known before the time of which the writer has been treating, by the boring at Chichester, passing

through 790 feet of Chalk, from top to bottom; and we also knew that at Southampton there was a greater thickness, over 850 feet having been passed through without reaching the bottom. The only additional information gained is from the Warren Farm well at Telscombe, east of Brighton, which, starting from only a few feet below the top, proves a thickness of nearly 960 feet. At the outcrop in the Isle of Wight the thickness is much greater than this; and it seems therefore that, as in the London Basin, there is some thinning towards the middle; but it is unsafe to generalize much from such scanty evidence.

While at Chichester, a thickness of over 80 feet of Upper Greensand was found, without reaching the base, at Telscombe there are but 10 feet of this division; and in this latter place alone (except in parts outside the Chalk-escarpment) has the Gault been reached. It has, however, been pierced to the base, giving the great thickness of 312 feet and being apparently underlain by Lower Greensand.

Along the border of the Chalk in eastern Sussex, it has been proved that the Gault is much thicker than had been thought, ranging up to more than 300 feet, indeed in one case 345 feet, or a trifle more than at Caterham. It has also been found that the Lower Greensand is very thin and sometimes absent, the Gault then resting on Weald Clay.

Except, therefore, in the neighbourhood of the outcrops of the Lower Greensand and the Weald Clay, where we may fairly infer extension underground, and for the one boring at Telscombe, we are still left in utter ignorance as to what formations next underlie the Upper Cretaceous in the Hampshire Basin. Indeed, there are places near the border of Hampshire and Berkshire, in what may be called the "neutral land" between the Hampshire and the London Basins, where we do not know what may be found 300 or 400 feet down, as in the Upper Greensand inliers of Kingsclere and of Shalbourn, especially in the former, where one cannot safely infer anything below the Gault, the top of which can hardly be far down at some spots, though the writer believes that even this has never been proved. On Sheet 81 of the so-called Horizontal Sections of the Geological Survey, published in 1870, the Gault is shown as underlying the Upper Greensand here, with Kimeridge Clay next beneath; but the writer has failed to find any evidence for this inference, and was fain to conclude that the author, who

was taken from us many years ago, feeling bound to fill the section in to sea-level, made the best guess that he could, based on the fact that at the distant outcrop to the north that succession holds on the map, for some distance.

Enough has now been said on the subject of the underground extension of beds, as proved by wells and borings in one part of England, to show how the subject itself could be extended.

Mr. JOHN GERRARD (H.M. Inspector of Mines) moved that the thanks of the members of The Institution of Mining Engineers be accorded to the Geological Society, for the use of their rooms for the meetings; to the Baker Street and Waterloo Railway Company; and to the Lords Commissioners of the Admiralty, Messrs. Coode, Son and Matthews and Messrs. S. Pearson and Son, for having opened their respective works to the inspection of members.

The Rev. G. M. CAPELL (Passenham) seconded the motion, which was unanimously approved.

Mr. J. BARROWMAN moved that a vote of thanks be accorded to the President for his services in the chair.

Mr. H. HALL (H.M. Inspector of Mines) seconded the resolution, which was cordially adopted.

The meeting was then closed.

The following notes record some of the features of interest seen by visitors to works, which were, by kind permission of the owners, open for inspection of members, during the course of the London meeting on June 14th, 15th and 16th, 1900:—

BAKER STREET AND WATERLOO RAILWAY.

The Baker Street and Waterloo Railway, about 5¼ miles in length, is formed by the construction of two separate parallel tunnels throughout its entire length, on the Greathead shield system. Starting at the Elephant and Castle, on the south side of

London, it passes Waterloo Station, thence under the river, up Northumberland Avenue, Charing Cross, the Haymarket, Regent Street, Portland Place, Regent's Park, Baker Street, Marylebone Station and Edgware Road, to Paddington Station. The site of the generating-station is about ¼ mile to the south of Waterloo Station.

The works were commenced by sinking two temporary shafts from a large timber-stage erected in the river Thames, on the western side of the Charing Cross railway bridge. From the river-stage, northward, the western or down-tunnel (towards Baker Street) has been driven beyond Piccadilly, and up Regent Street. The up-tunnel has been completed between the river-stage and the statue of King Charles at Charing Cross, and between Regent Street and a point in the Haymarket, opposite Her Majesty's Theatre. The tunnels at Baker Street have been driven under the St. John's Wood Railway, and underneath the Regent's Park; the down-tunnel to the north side of the Park Square Gardens, and the up-tunnel to the western side of the Outer Circle Road.

Southward of the river-stage, the down-tunnel has been constructed nearly across the river, and the difficult operation of driving through the water-bearing gravel in the bed of the Thames has been successfully accomplished.

The permanent shafts at stations for the reception of the lifts have been sunk in Baker Street and Piccadilly, and one of the shafts is in progress at Waterloo. The up-station tunnel at Baker Street has been completed. Both station-tunnels at Piccadilly Circus are finished, and at Charing Cross one tunnel is completed and the other is in progress. At the Thames Embankment Station, the up-tunnel is finished.

Recent experience has demonstrated that for this railway electricity is superior to steam power. There will be complete absence of smoke and noxious vapours, as the construction of separate tunnels will secure effective ventilation, and the atmosphere will be cool in summer and warm in winter. The speed of the trains will be about 13 miles an hour, including stoppages. The entire distance between the Elephant and Castle and Paddington will be accomplished in about 25 minutes.

DOVER HARBOUR WORKS.*

By J. C. COODE, M. Inst. C.E. and W. MATTHEWS, M. Inst. C.E.

Many interesting records, extending back more than 400 years, still exist of works proposed and executed for the formation and improvement of the harbour at Dover; necessarily these older records apply chiefly to works on the sites now occupied by the Tidal Harbour and the Wellington and Granville Docks.

In the year 1840, a Royal Commission was appointed to survey the harbours of the south-eastern coast. It is unnecessary to quote the recommendations of the Commission with regard to other ports, but with reference to Dover they remarked:—

> This harbour, as the principal port of communication between Great Britain and the Continent, has been regarded at all times as a place of the greatest importance.

It may be of interest to quote a somewhat similar but more detailed opinion given by Sir Walter Raleigh in a memorial presented to Queen Elizabeth in the year 1580:—

> No promontory, town, or haven, in Christendom, is so placed by nature and situation, both to gratify friends and annoy enemies as this town of Dover; no place is so settled to receive and deliver intelligence for all matters and actions in Europe, from time to time; no town is by nature so settled, either to allure intercourse by sea or to train inhabitants by land, to make it great, fair, rich and populous; nor is there in the whole circuit of this famous island any port, either in respect of security or defence, or of traffic or intercourse, more convenient, needful or rather of necessity to be regarded, than this of Dover, situated on a promontory next fronting a puissant foreign king, and in the very streight, passage and intercourse of almost all the shipping in Christendom.

Having completed their inspection, the Commissioners reported as follows:—

> The situation which appears to us of the greatest importance, and at the same time affords the most eligible position for a deep-water harbour, is Dover Bay. Independently of its proximity to the Continent, this bay possesses con-

* Reprinted by permission from the *Report of the Sixty-ninth Meeting of the British Association for the Advancement of Science*, held at Dover in September, 1899, page 479.

siderable advantages; the depth of water at 400 yards from the shore is 2 fathoms at low water of spring tides, and but 6 fathoms at 1,100 yards, which therefore affords sufficient width for the construction of a capacious deep-water harbour, without getting into such a depth for the site of the piers or breakwater as would greatly add to the expense of the works.

The works recommended by the Commissioners were described as follows:—

The principal feature of the proposed plan is a breakwater at the average distance of 1,000 yards from the shore, with piers projected from the land towards its eastern and western ends.

The area at low water enclosed within the works would have been 450 acres, of which 320 acres would have been seaward of the 2 fathoms line. It was pointed out that either one entrance, or two entrances, could be provided as desired. The advantages of two entrances were stated to be—

That vessels might enter or leave the harbour with the wind from any quarter, and a ready access be afforded to the mouth of the present harbour from the western entrance, without passing through the centre of the new harbour.

On the other hand, the provision of only one entrance in the middle of the breakwater would have the advantage of rendering the interior of the harbour in some degree more quiet. The Commissioners were in favour of two entrances. The estimated cost of the proposed works was £2,000,000.

Chiefly on account of the terms of a report on shipwrecks made by a Select Committee of the House of Commons in 1843, a further Royal Commission was appointed in 1844 to consider:—(1) Whether it was desirable that a harbour of refuge should be constructed in the Channel. (2) What site would be the most eligible for such a harbour on account of its combining in the greatest degree the following grounds of preference:—(*a*) That it should be of easy access at all times of the tide to vessels requiring shelter from stress of weather; (*b*) that it should be calculated for a station for armed vessels of war in the event of hostilities, both for purposes of offence and defence; and (*c*) that it should possess facilities for insuring its defence in the event of an attack by the enemy.

In reporting, the Commissioners agreed with their predecessors of 1840 in pronouncing a favourable opinion of Dover as a site for a harbour of refuge, but gave special attention to the

quality of the anchorage and the liability of the harbour to silt up. At the instance of the Commissioners, Captain Washington, in command of H.M.S. *Blazer*, made practical trials of the holding qualities of the anchorage, and reported in the following terms:—

> Thus the tough nature of the holding ground, so much better than, from common report, I had anticipated, having disabled one anchor and parted the cable from the other, and the fact of two large ships having also parted their cables in recent gales, appeared to be decisive as to the good quality of the anchorage, nor, after the trials I have witnessed, should I have any hesitation in riding out a gale of wind in Dover Bay in its present state. How much less so when enclosed by a breakwater!

The probability of the deposit of silt in an enclosed harbour could not be so definitely determined; samples of water taken in various positions and depths showed that the quantity of matter in suspension varied from 3 to 13 grains per cubic foot in calm weather, and from 10 to 54 grains in a strong south-westerly breeze. The Commissioners were of opinion that more extensive experiments were necessary, and that these should be continued for the space of a year, in all circumstances of weather.

They submitted a design, and, pending further consideration of the general scheme, urged the immediate commencement of "that portion which is to commence at Cheeseman's Head." For the information of visitors, it may be well to say that the work thus described is that now generally known as the "Admiralty Pier."

In the next year, 1845, a further Commission was appointed to consider plans submitted by eight of the leading engineers of the day, and reported that the form of the harbour should be practically that recommended in the previous year.

Further observations on the quantity of silt held in suspension were made, and the report pointed out that if liability to silt were deemed an objection, it would be idle to attempt such works on any part of our coast. To minimize the difficulty it was considered better to admit only the quantity of water required to maintain the level in the harbour without sensible current, than to permit a free tidal current which would sweep through without causing a deposit.

As an instance supporting this contention, reference was made to Kingstown, in Dublin Bay, where the harbour, although in the neighbourhood of numerous sandbanks, and with a single entrance in the fair line of the tide, remained, after twenty years' experience, free from any permanent deposit.

The only other point considered by this Commission to which reference need now be made was the mode of construction. After receiving very contradictory evidence, the system of upright walls was recommended in preference to sloping stone breakwaters.

As a result of these inquiries and recommendations the contract for the first portion of the Admiralty Pier was let in October, 1847, and, excepting only a small addition to its seaward end, it was completed in 1871. Its total length, including the turret, is about 2,000 feet. It will be universally admitted that, considered either as an engineering structure or as affording accommodation for an enormous passenger traffic, this pier bears favourable comparison with any work of a similar character, and reflects the greatest credit on its designers and builders.

On only one occasion since its completion has any serious accident occurred to the Admiralty Pier. This took place during an exceptionally heavy gale on January 1, 1877, and was confined almost entirely to the superstructure above quay-level. The damage was clearly due to the thickness of the parapet, as originally designed by Messrs. Walker and Burgess, having been very largely reduced with a view to give greater width for passenger platforms. At the time the pier was designed it was not contemplated that it would be used for train service.

Between the years 1869 and 1889 many designs were put forward for the improvement of the port; these need not be now considered, but it may be of interest to note that a Committee appointed in 1881 to consider certain questions relating to the employment of convicts in the United Kingdom reported in favour of a continuation of the system under which large public undertakings, such as the fortifications and breakwater at Portland, the great basins at Chatham, and other similar works, had been constructed. From all the schemes laid before them, the Committee selected on account of their magnitude, their importance from a national point of view, and as well suited for the employment of prison labour:—(1) The construction of a pier and breakwater at Dover so as to form with the Admiralty Pier a large harbour similar to that at Portland; and (2) the formation of a harbour of the same character at Filey in Yorkshire.

The large convict prison on the East Cliff was constructed with the intention of carrying out the recommendation of the Committee as regards Dover, but, for several years, no further steps were taken.

On reference to Fig. 1, it will be seen that the Admiralty Pier must give fairly good accommodation for landing and embarking even during ordinary gales from the south-west. During exceptional storms, broken water is carried over the parapet, and access to and landing from steamers is attended with risk. For use during moderate winds from the east and north-east, landing facilities have been provided by the construction of stages on the western face of the pier. It is, however, evident that with winds from the south-east, the pier is exposed on each face, and serious delay and inconvenience have been thereby caused. To improve the then existing conditions, the Dover Harbour Board in 1890 consulted the late Sir John Coode with a view to the construction of a sheltered deep-water harbour.

The work was sanctioned by Act of Parliament in 1891.

The design recommended and adopted is shown in Fig. 1. The scheme, for convenience of description and to distinguish it from the larger national works, is frequently designated "the Commercial Harbour," and will be so named whenever it is referred to in this paper.

The sheltering works proposed were: (1) An East Pier, running about south-east from the Clock Tower, and (2) an extension in an approximately easterly direction of the Admiralty Pier. The sheltered area which would have been enclosed was 56 acres, and within this it was proposed to reclaim an area of about 5 acres lying between the inner end of the Admiralty Pier and the entrance to the existing Inner Harbour. From the front of the reclamation, two jetties, each 400 feet long and 100 feet wide, were to be constructed. They were to be furnished with commodious landing-stages, having platforms at various levels to accommodate steamers at all states of the tide, and were to be connected with the railway-systems of the South-Eastern and London, Chatham and Dover Companies. A depth of 15 feet at low water was to have been provided alongside and in the approach to the jetties.

The only part of this scheme commenced up to the present time is the East Pier. The contract for its construction was let to Sir John Jackson in 1892, and the memorial-stone was laid by H.R.H. the Prince of Wales on July 20th, 1893.

Towards the end of 1895, the Admiralty instructed the authors to prepare a design for an enclosed harbour suitable for the accommodation of H.M. navy. For this purpose it was

necessary that a detailed engineering survey should be made, including many thousand soundings extending about 1¼ miles from the shore, borings to ascertain the character of the foundation on the lines of the several proposed works, and observations on the direction and strength of the tidal currents at various periods.

The works, which, as the result of the survey, were recommended (Fig. 1), are:

(*a*) An extension of the Admiralty Pier in an east-south-easterly direction for a length of 2,000 feet, practically doubling its present length.

(*b*) An East Arm commencing against the chalk-cliffs a few hundred feet east of the eastern boundary-wall of the convict prison-enclosure. The direction of this work will be approximately south-by-west, and its length 3,320 feet.

(*c*) An isolated breakwater, 4,200 feet long, forming the southern protecting arm and running generally west-by-south and east-by-north, but turning towards the north at its eastern end. The average depth, at low water, of ordinary spring tides on the line of this South Breakwater is 42 feet.

(*d*) The reclamation of 21 acres of the foreshore to the eastward of the Castle Jetty. The reclamation is now being formed by the construction of a substantial sea-wall, founded on the chalk, a little above the level of low water of ordinary spring tides. The length of the retaining-wall from the Castle Jetty to its junction with the East Arm will be 3,850 feet, of which length the foundations are now laid and the wall brought up to varying levels for 2,000 feet.

Between the seaward end of the East Arm and the eastern end of the South Breakwater there will be left an entrance 600 feet wide, with a navigable low-water depth of 7 fathoms. A second entrance will be formed by the head of the Admiralty Pier-extension and the western end of the South Breakwater. This will be 800 feet wide, and it will also have a depth of about 7 fathoms.

It will be observed that the western head of this last-named entrance will be between 400 and 500 feet south of the eastern head. This arrangement was decided on, in order to assist vessels entering the harbour at times when the east-going current is running at its greatest velocity of nearly 4 knots per hour. The overlap will also facilitate the entrance or exit of vessels during south-westerly gales.

The total length of sheltering works to be constructed is 9,520 feet, and the area enclosed, exclusive of the Commercial Harbour will be 610 acres at low water, 322 acres being outside the 5 fathoms line, and 171 acres outside the 6 fathoms line.

Comparing these figures with the proposals of the Commission of 1844, and allowing for the existing Admiralty Pier, which was not commenced until 1847, it is found that by the addition of only 700 feet of sheltering works, the following gain of area will be obtained:—

At low water	30 acres
At 5 fathoms	52 acres.
At 6 fathoms	59 acres.

This comparison appears to be perfectly fair, as the depth on the lines of the several works of the two designs are practically identical.

The contract for the Admiralty Harbour was let in 1897 to Messrs. S. Pearson & Sons, of London.

Having generally described the works for the formation of the Admiralty Harbour and the original proposal for the Commercial Harbour, reference may be made to the modified proposals for the latter (Fig. 1).

In the year 1890, when the Commercial Harbour was designed, there was no expectation that the Government would, in the near future, consider it desirable to proceed with the large national work, and the design was consequently drawn up so that it might be complete in itself. It will be apparent that, as soon as the 2,000 feet extension of the Admiralty Pier was decided on, the smaller extension of the same work became unnecessary. As the construction of the East Pier had, fortunately, not reached the point at which it would have commenced to curve to the south-west, the Harbour Board were advised that by continuing the work in the direction in which it had been commenced, and by a short addition to its length, a more capacious harbour would be obtained without in any way interfering with the Admiralty scheme.

The proposal being adopted by the Board, and sanctioned by the several Government Departments, the pier has been built on the line shown in Fig. 1, and is now rapidly approaching completion.

The construction of the short western arm has consequently

been abandoned, and, as a substitute, a short spur will eventually be run out from the extension of the Admiralty Pier.

The low-water area of the Commercial Harbour as laid down in 1890 was 56 acres, and as now modified it will be 75 acres. This will be admitted to be a substantial increase, more particularly when it is noted that the addition is entirely outside the 5 fathoms line, and that it will be obtained with little or no expense to the Harbour Board beyond that entailed by the original proposal.

Such are the objects for which the various piers for both the Admiralty and Commercial Harbours have been adopted.

Passing from the question of the design of the harbours to that of the method of construction of the several works by which they will be formed, it is proposed to describe in some detail the operations employed in the building of the East Pier. This particular pier is selected, because the work is so far advanced that the results can be inspected, and also because the principle adopted for the solid portion forming the outer length is similar to that on which the several Admiralty works will be built.

The pier is formed firstly by 1,260 feet of open iron viaduct, and secondly by a solid masonry work, 1,650 feet long.

The open work was introduced chiefly to afford free circulation of the water in the Commercial Harbour, but had it been necessary to make it solid much additional expense would have been incurred, as the seas caused by heavy easterly and south-easterly winds would have been concentrated in the re-entering angle between the new work and those then existing on the sea-front, and would probably have caused much damage to the latter. It is almost unnecessary to say that the adoption of open instead of solid work represented a substantial decrease in cost.

To carry the shore-end of the viaduct and to form a retaining-wall to the inclined approach leading from the promenade-level, a masonry abutment, founded on concrete cylinders carried down to the chalk, was formed close to the Granville Clock Tower at the western end of the Esplanade.

The viaduct is built in spans of 40 feet, each pier consisting of three hollow wrought-iron piles strongly braced together. The width at deck-level is 30 feet, providing for a central roadway of 18 feet, and a footpath on each side of 6 feet. The level

of the deck is 19 feet above high water of ordinary spring tides, and it is therefore not liable to damage even in the heaviest seas. At three points in the length of the work, the number of piles in a few bays is increased to five, giving a deck-width of 56 feet, while the spans are reduced to 20 feet. Considerable additional stability, both laterally and longitudinally, is thus obtained. On the piers so constructed longitudinal lattice-girders carry a platform or deck of corrugated-iron plates.

At first, the piles were fitted with steel points, and were driven about 25 feet below ground-level, inclusive of about 15 feet into the chalk which exists over the whole of Dover Bay. Contrary to expectation, the bearing power of these piles was not found sufficient, and cast-iron screws, 3 feet 6 inches in diameter, were substituted for the steel points.

The screws for a few piers proved satisfactory under the 100 tons dead-weight test to which each central pile was invariably subjected, but during the application of the test-load at a pier about 200 feet from the shore, the pile, much to the surprise of all present, suddenly sank about 20 feet vertically. Borings taken at close intervals round the site of the pile showed that its position was exactly at the bottom of a cavity in the chalk, the surface of which sloped down to the pile in all directions.

The accident proved that the quality of the chalk was extremely variable, and a change in system became necessary. Under the centre of each pier, a cast-iron cylinder, 8 feet in diameter, was sunk into the chalk and filled with concrete, the central pile or column being erected on a granite-block bedded therein. The two side piles, on which the loads are considerably less than on the centre, were, after the accident before described, fitted with cast-steel screws, 4 feet in diameter, and no further trouble has been experienced.

It may be interesting to members to learn that when excavations were made in the cylinder, on the site of the pile which failed to reach the depth to which the screw had originally penetrated, the blade was found broken into three pieces, having parted from the boss very close to the pile-shank. The explanation of the accident appears to be that parts of the screw-blade were bearing on hard chalk or flints, while other parts, as well as the point of the boss, were in soft material lying in the cavity indicated by the borings as already described.

The corrugated-iron deck of the viaduct will be filled with concrete as soon as the outer or solid portion of the pier is completed. The surface, both of roadway and footpaths, will be formed of asphalte.

The solid masonry portion of the pier has a length, including the head, of 1,650 feet, with a width at quay-level of 35 feet, and at foundation-level of 48 feet. The general level of the surface is 10 feet above high water, but at the inner end this rises on a gradient of 1 in 40 to meet the higher level of the viaduct-deck. When originally designed as a sheltering work, it was intended to provide on its eastern side a parapet somewhat similar to that on the Admiralty Pier. As shelter will in time be given by the works of the Admiralty Harbour, this parapet will now be omitted.

For the construction of the solid work, a substantial temporary stage carrying three powerful goliath cranes was erected. The outermost goliath worked a heavy grab, by means of which the loose material overlying the chalk was excavated. From the central goliath was slung an exceptionally large diving-bell, from which the excavation and levelling of the chalk-bed were effected. This part of the work was very heavy, as no block was allowed to be set at less than 3 feet below the surface of the solid chalk. The innermost goliath was used for unloading the blocks brought on trucks, over a temporary connecting viaduct now removed, and for setting them in the pier.

The blocks throughout are of concrete, those above low-water level being faced with granite. They vary in weight from 12 to 20 tons. Below low water they are set without mortar, but are well bonded and keyed together by joggles, inserted into recesses cored out at the time when the blocks are moulded. Above low-water, the blocks are set in Portland cement-mortar, and are also keyed by joggles.

Probably some members will visit the works and they will then be able to see many details, a description of which time does not allow to be included in this paper. Among these details, the concrete-mixing machinery, the character of the moulds used in the manufacture of the blocks, and the methods employed for lifting them, will probably be of most general interest.

The pier will be fitted with two fendered berths on each side and a landing-stage, for the accommodation of steamers, on the western side. Landing-steps, mooring-bollards, lamps, gas and water services are also to be provided.

The pier terminates in a circular head, 52 feet in diameter, and on this a lighthouse of concrete masonry, faced with granite, will shortly be constructed.

It has already been indicated that the type of structure adopted for the East Pier is similar to that which is to be followed in building the works for the formation of the Admiralty Harbour. On account, however, of their exposed positions and the heavy wave-stroke to which they will be subjected, the latter will necessarily be of considerably greater dimensions; comparison of the section of the East Pier with the section of the Admiralty-Pier extension confirms this statement.

The cross-section of the Admiralty-Pier extension is worth notice, if only on account of the magnitude of the temporary works. The staging, of which a short length can now be seen projecting from the end of the turret, is probably more massive than any similar structure hitherto erected in the sea. The height from the ground-level to the highest point of the goliath is 150 feet, and the total width of the stage at rail-level is 115 feet.

The area to be reclaimed between the East Arm and the Castle Jetty will be filled with chalk obtained by sloping or scarping the cliffs immediately behind the wall. The ground so formed will, in the first instance, be utilized for the formation of the block-building yards and the erection of the workshops, stores and offices required for the construction of the East Arm and South Breakwater.

A temporary yard for the service of the Admiralty-Pier extension has been formed on the beach in front of the South-Eastern Railway Company's Town Station.

The blocks for the reclamation-wall are built at Sandwich, where a large quantity of ballast—sand and shingle—eminently suitable for the manufacture of concrete has been obtained by the contractors. The blocks, and a considerable quantity of ballast, are now brought from Sandwich by lighters, but a light railway at present under construction will, when completed, deliver material direct on to the reclaimed yard. Ballast is also obtained from Dungeness, but, being practically free from sand, requires to be mixed with the material from Sandwich before it is used for block-making.

Portland cement of the highest quality, manufactured under continuous inspection, analysis and test, is alone used in any of the permanent works.

It is feared that the patience of the members must already have been severely tried by the length of this paper, and a subject so largely technical. Even at the risk of being tedious it is considered that this opportunity should not be lost for a reference to the inconvenience, discomfort, and serious delay experienced during last winter, on account of the interruptions to the passenger service from the port. That these interruptions were largely due to the position of the works during a season unexampled for the number of heavy south-westerly gales cannot be questioned.

The exact cause of this will be easily understood by reference to Fig. 1 on which the direction of south-westerly winds is represented. The seas brought up Channel by gales from and near this quarter, and outside the shelter of the Admiralty Pier, travel on until they strike the western face of the East Pier and recoil therefrom on to the landing-stages on the eastern side of the Admiralty Pier, which stages in similar gales had previously been available. That this action would occur and become stronger as the East Pier advanced seaward, without a corresponding advance of the Admiralty Pier, was evident before the inconvenience was actually experienced.

In order to minimize the delay two steps were taken by the Harbour Board. Firstly, an entirely new landing-stage was constructed near the outer end of the Admiralty Pier, where the disturbance was much less felt than at the stages nearer the shore. This was frequently available when it was impossible to approach the older berths. Secondly, negotiations were opened with a view (if possible) to delay further progress with the East Pier until the extension of the Admiralty Pier was sufficiently advanced to give the required shelter. It was, however, found that the cost of retarding the work would be so great that the financial position of the Board did not justify the adoption of this course.

The advance of the masonry-extension of the Admiralty Pier is not likely to be sufficient to give much additional shelter during the coming winter, but the large number of piles in the temporary stage will, as experience has shown to be the case in other places, no doubt assist in breaking up the seas; thus it may reasonably be expected that delay will be on a smaller scale than was experienced last year. In Sir John Coode's original design, the whole of the East Pier during south-westerly winds would have been inside the shelter of the Admiralty Pier, as it then existed.

The writers hope that it has been made clear that had it not been for the change of plan consequent on the decision of the Admiralty to carry out the splendid work lately started, no disturbance of the traffic would have been experienced. Is it unwise to suggest that the inconvenience, serious as it has been, is only temporary, and that to obtain such a harbour—probably second to none—much greater sacrifices would willingly be made by almost every port in the kingdom?

In conclusion, attention may be drawn to the peculiarly favourable situation of Dover, with reference to several Continental ports. The proverbial schoolboy knows that Dover is the nearest port to Calais. It is, however, believed that very few persons, whether schoolboys or of more mature age, are aware that Dover is also nearer to Boulogne than Folkestone; nearer to Flushing, and therefore to Antwerp than either Queenborough or Harwich; that as regards Dieppe, Newhaven has the advantage by only 7 nautical miles, and Southampton, only a similar advantage with reference to Havre.

Again, compare Dover with Southampton as a "port of call" for foreign liners from Antwerp, Rotterdam, Hamburg, and all ports to the north. The comparison will hold good whether these liners are bound for the United States, *via* the Lizard, or for South Africa, India, China, and Australia, etc., *via* Ushant. The call at Dover would involve no complicated course such as that necessary for Southampton, *via* Dungeness, the *Royal Sovereign* lightship, the Owers, Spithead, and Southampton Water.

The course on leaving the "port of call" is also in favour of Dover, as after passing Dungeness a straight course could be set for either the Lizard or Ushant, no variations corresponding to Southampton Water, the Solent, and the Needles being requisite. Not only would there be a saving in distance, but the risks of fogs, so prevalent at the back of the Isle of Wight, would be much reduced. Under these circumstances it is not surprising to learn that proposals have been made to utilize Dover in connection with several lines of ocean-going steamers, and that the Harbour Board have already received inquiries on the subject.

Finally, it is hoped that, with the schemes for the improvement of the port fully before them, the members will cordially agree with the forcible language of Sir Walter Raleigh—"nor is there in the whole circuit of this famous island any port more convenient, needful, or rather of necessity to be regarded, than this of Dover."

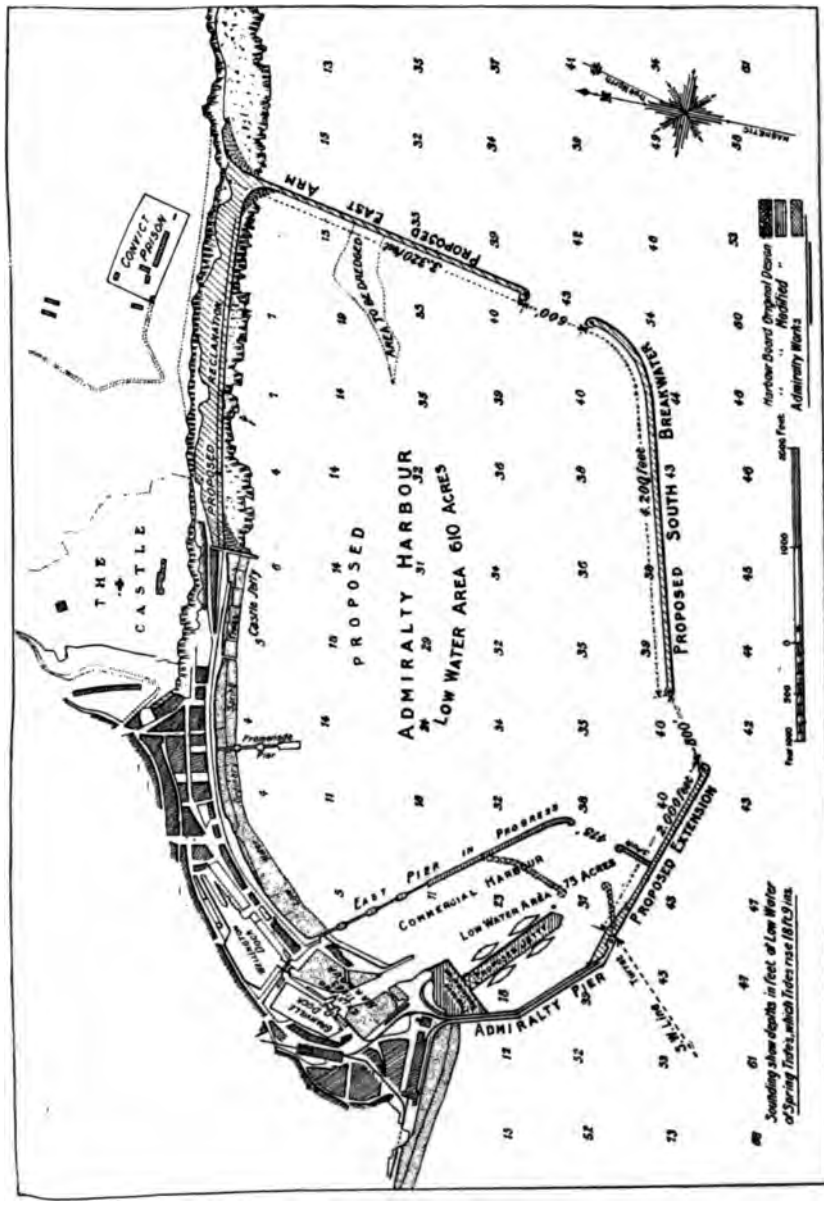

FIG. 1.—PLAN OF PROPOSED WORKS AT THE ADMIRALTY HARBOUR, DOVER. SCALE, 2,000 FEET TO 1 INCH.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD,
FEBRUARY 24TH, 1900.

MR. W. H. CHAMBERS. PRESIDENT, IN THE CHAIR.

Mr. JAMES KEEN read the following "Description of the Sinking of Two Shafts through Heavily Watered Strata at Maypole Colliery, Abram, near Wigan":—

DESCRIPTION OF THE SINKING OF TWO SHAFTS THROUGH HEAVILY-WATERED STRATA AT MAYPOLE COLLIERY, ABRAM, NEAR WIGAN.*

BY JAMES KEEN.

Before describing the work of sinking the Maypole pits, the writer would like to say a few words as to why it was decided to put down such very powerful pumping-plant, and the reasons for taking precautions for dealing with a large volume of water. He did not suppose that anything except the knowledge that there was a very large area of Abram cannel to be worked (provided that the pits could be sunk successfully), would have led the Moss Hall Coal Company, Limited, to undertake the task. Most of the members know something about the value of this cannel, which yields the following products per ton: 14,111 cubic feet of 39 candle-power gas, with a large percentage of valuable residuals, and about 7 cwts. of good coke.

Some thirty years ago, an attempt was made to sink two pits on the estate, but owing to the large volume of water encountered the undertaking was abandoned, and the pits filled up. After

* Reprinted by permission from the *Transactions of the Manchester Geological Society*, 1899, vol. xxvi., pages 122 to 152.

pumping for about 12 months at the shafts described in this paper, the farmer on whose land the old pits were situated called the writer's attention to the sudden subsidence of one of them, the ground having sunk 2 feet below the surrounding surface; and no doubt this was owing to the water being drained out of the pit. This was nearly 1 mile from the new pits.

Another attempt was made about 24 years ago to sink to these valuable mines, about 2,100 feet from the present sinking, and about 120 feet on the dip. After pumping the water found in the top Red Sandstone for several years, they sank through it, but as soon as they came to the Brown-red Sandstone below the Permian Marls, they found so great a volume of water that they abandoned the undertaking, and the pit now stands with 300 feet of water in it. It is about 153 feet from the surface, and runs to the Maypole pits at that level.

Before commencing to sink, several bore-holes were made in different parts of the royalty, two being bored to the first seam of coal. It was decided to sink within 150 feet of one of these bore-holes; the Red Sandstone was passed through at 450 feet, and the sinking afterwards proved that the boring gave a correct account of the strata passed through. A diamond drill was used, and brought out a core of the strata.

The estates, from which we are about to work the mines, are surrounded by collieries at present working, and as there is no water at any of these pits, the water found at the Maypole pits can only exist in the area to be worked. This area is thrown down on all sides by large faults, and it is entirely covered with Red Sandstone, which is not found at the adjoining collieries.

When sinking was commenced it was thought that a large quantity of water would be found in the top band of Red Sandstone, which was passed through at 165 feet; then followed about 45 feet of Red Sandstone intermixed with red metal, which contained water, but down to this depth the quantity of water did not exceed 14,000 gallons per hour. The writer is of opinion that, during the previous trials, these strata had been pumped partly dry, as for several years enormous volumes of water were being pumped with very powerful machinery, and as soon as they got through the Permian Marls into the Brown-red Sandstone so much water was encountered that they abandoned the attempt to sink the pits.

The writer thinks that this conclusively proves that no surface-feeders can pass through the 72 feet of strong clay found at the surface, and all the evidence of the Maypole sinking proves that the water pumped during the last three or four years has not been derived from surface-feeders.

After getting through the Red Marls, at 339 feet, a large feeder was found, and as the sinking proceeded further feeders were found, always in floors. None of the feeders issued from vertical fissures, and after pumping for a time they became smaller, and finally ceased. So that to-day there is practically no water, except that derived from a floor where the Red Sandstone lies upon the Coal-measures. This feeder, when first found, was about 90,000 gallons per hour, but it has become gradually less, and yields now only about 60,000 gallons per hour. This water was pumped instead of being tubbed back, because there are three or four valuable seams of coal so near to the Red Sandstone that the breaking of the roof in working these mines would have brought the water into the workings.

The most striking features from a geological point of view were, first, the great difference found in passing through the clay. At No. 1 Pit, it went right down to the sandstone, but at No. 2 Pit, 150 feet away, 13 feet of running sand was found at the bottom of the clay, and 3,000 gallons of water per hour coming right down to the top of the Red Sandstone; some of it was exactly like the pebbly beach so often seen on the sea-shore. At about 360 feet, there was a hard, bright, glittering looking sandstone, some of it having the appearance of rock-salt, and a pick would scarcely touch it; it had a slight saline taste, and after a few hours' exposure to the atmosphere it wasted away, similar to ice thawing, and in a very short time a hole had run into the side of the shaft, 20 feet deep, 10 feet wide and 15 feet high; this had to be made secure as quickly as possible, otherwise very serious trouble would have occurred. We also found below this, at about 405 feet down, a bed about 6 feet thick containing round balls, from the size of a pea up to the size of a billiard ball, very hard, and perfectly spherical, which when put into the fire exploded and gave off a strong sulphurous smell. These were portions of sandstone, in which the grains are cemented together by iron-pyrites. A bed of flattened round calcareous concretions was found in the Permian Marls. No fossils were found except in the metals between the

various seams of the Ince mines series, in which remains of plants were very plentiful.

The sinking of No. 1 shaft was commenced on May 31st, 1895, and the first bricking-ring was laid at a depth of 78 feet; the whole of this sinking was in strong clay, and elm-rings, 6 inches square, close timbered with battens, 2 inches thick, were inserted.

On July 2nd, 1895, water was found at a depth of 108 feet and a water-ring was put in at that point; at 117 feet more water was found than could be wound, and sinking operations were discontinued for a time.

It was decided to use an Evans straight-line sinking-pump, having a 7 inches ram and a steam-cylinder, 14 inches in diameter. and 24 inches stroke, equal to pumping 14,000 gallons per hour. This pump was slung in chains, with large blocks for lowering it.

Sinking was resumed on September 25th, 1895, and the water was passed through at a depth of 192 feet, where a water-ring was inserted to catch the water, which amounted to 12,000 gallons per hour. The pump was fixed on a bearer, and pumped out of a tank fixed at this point; and from this depth the sinking proceeded, passing through the Red Sandstone at 210 feet, after which there was red metal for 189 feet; and on January 8th, 1896, at the depth of 339 feet, another feeder of water was found.

Another Evans straight-line sinking-pump was slung, with a steam-cylinder 24 inches in diameter, and a double-acting ram, 13 inches in diameter, and 24 inches stroke, equal to pumping 40,000 gallons per hour, at 35 strokes per minute, and when fully equipped with a pipe-column it weighed over 25 tons. This pump was slung on a steel rod, $3\frac{1}{2}$ inches in diameter, in 10 feet lengths, and was lowered by a screw, $5\frac{1}{2}$ inches in diameter, working through a worm and worm-wheel, driven by an engine with two cylinders, 8 inches in diameter. The pipes were made in 10 feet lengths, corresponding to the length of the rods, and a length of 10 feet was lowered each time, the slide on the suction-pipe of the pumps allowing of a movement of 12 feet. While sinking and using this apparatus, the pump could be lowered 10 feet in 25 minutes, including stopping and starting.

All the pipes used were made of steel with acme joints, there are some in use now that have been fixed for two years; they are light, strong and durable, and have never required repairing.

Each of the Evans pumps was fitted with steam- and exhaust-pipes, 5 inches in diameter, and the rising main was 9 inches in diameter. These pipes were hung in the pit and swung about without having any injurious influence on the joints.

Proper stages were erected for the men in charge of the pumps, and the writer thinks that it is of the highest importance in sinking operations to place a man in charge of each pump.

Sinking was continued to a depth of 351 feet, until a feeder of about 27,000 gallons of water per hour was tapped. It was then decided to make a pump-house and an underground lodge at this point for a Hathorn-Davey pumping-engine. The workmen commenced making the pump-house and lodge on March 17th, 1896.

At the same time, it was decided to erect a Pearns duplex pump at this depth, to supplement the Evans pumps; and while the lodge-making was still in progress the Pearns pump was started on May 1st, 1896. The rams were 10 inches in diameter and the steam cylinders 24 inches in diameter, the stroke being 18 inches. The pumping capacity of the Pearns pump is 42,000 gallons per hour, when running at 35 strokes per minute.

On June 23rd, 1896, the Hathorn-Davey ram-pump was started, with the engine on the surface, and a ram, 24 inches in diameter, having a stroke of 10 feet. Sinking was resumed to a depth of 363 feet, and a further quantity of water of 60,000 gallons per hour was tapped. This water came in so far below the fixed Pearns pump that the latter could not deal with it; so a length of tubbing, made of boiler-plates, with 18 inches cement brickwork and cement-concrete backing, was inserted, and so elevated the water, 10 feet, to a cistern. This enabled the Pearns pump to deal with what was beyond the capacity of the Evans pumps.

It will readily be understood that there were the usual pumping accidents, which are quite frequent in sinking operations. On July 2nd, 1896, the large Hathorn-Davey pump burst a clack-box cover, and, to prove that mishaps in pumping do not come singly, the Evans pump, by overwork, also failed, the water rose to within 180 feet of the surface, and all the pumps were left under water. The Evans pump was raised, and another added of the same size, sustained by similar gear on the opposite side of the shaft, and the water pumped down.

Sinking was resumed on July 27th, 1896, and continued until August 6th, when a further large feeder was tapped, making the

total quantity of water then being pumped to the surface, 160,000 gallons per hour. A No. 11½ pulsometer-pump was placed at this point to force the water to the Hathorn-Davey pump, and the two Evans pumps were fixed on bearers, as they worked much more satisfactorily at this depth when fixed than when hung on slings.

Sinking then ceased at No. 1 shaft and was not resumed until more than a year later, namely, November 12th, 1897, when sinking was resumed at No. 1 pit, and the water was passed through in exactly the same manner as in No. 2 pit; the sealing-ring was inserted, and as the pit is 24 feet on the dip of No. 2 pit, most of the water is pumped from behind the sealing-ring in the No. 1 pit. Sinking has been continued since November, 1897, but if either pit had to be stopped for anything, this pit has been allowed to stand. To-day, it has been sunk through the Ince mines, and is within 100 feet of the Bickershaw 7 feet seam.

The sinking of No. 2 shaft was commenced on September 1st, 1895. It was suggested to the writer that the pit could be sunk through the clay, without the elm-rings and battens being used, as explained in describing No. 1 pit, but he preferred to run no risk, as he has always held that it is unwise to do so, especially if only a little labour be saved.

As before mentioned, the clay in No. 1 shaft extends down to the rock. In No. 2 pit, at a depth of about 60 feet there was sand and pebbles, and there was quicksand down to about 80 feet, with from 2,000 to 3,000 gallons of water per hour. There was the greatest difficulty in keeping the shaft in passing through this treacherous ground, and the writer is satisfied that if he had not had the shaft close timbered from the surface it would certainly have been lost; as it was, the whole of the timber moved from top to bottom, and the whole of this timbering was slung from the surface with chains, attached to large balks placed across the top of the shaft. A large winding-engine had been erected to wind permanently from this pit, and had the pit been lost it would have been a very costly matter.

The sinking was resumed to a depth of 87 feet, when it was stopped by water, although the ground appeared open, and No. 1 shaft was only 150 feet away and had a considerably greater depth than this. Sinking was recommenced on September 8th, 1896, using the small Evans sinking-pump, that had been in use in the other shaft, as the water had disappeared.

The sinking proceeded to a depth of 345 feet, and more water being found, a tunnel was commenced between the two shafts; this was completed and bricked on December 7th, 1896. Sinking was continued again on that date, and more water being found, a syphon, 4 inches in diameter, was placed through the tunnel, which enabled the sinking to be continued until December 13th, 1896, down to a depth of 360 feet.

On this date, the Hathorn-Davey pump burst its bottom clack-box, which resulted in the water rising in No. 1 shaft up to the Pearns pump. The two Evans pumps were raised to the same level, they all delivered the water to the surface, and the water that these pumps could not deal with passed through the tunnel into No. 2 shaft.

The winding of water from No. 2 shaft was commenced on December 18th, 1896, and up to January 10th, 1897, in this way an average of 47,000 gallons per hour was raised without a break. The tank or barrel held 1,010 gallons, having a clack 24 inches in diameter in the bottom. During an experimental hour, 59,000 gallons of water were wound, and the writer knows of no other case in which so much water has been wound in the time from so great a depth by a single water-barrel.

When the pumps had resumed work, almost immediately further water was tapped in No. 2 shaft, and a No. 11½ pulsometer-pump was inserted: the guaranteed capacity being 80,000 gallons per hour, against a vertical height of 70 feet, with steam at a pressure of 60 pounds per square inch. On January 26th, 1897, at a depth of 369 feet, a further large feeder was found, and another pulsometer-pump of the same size was required, both being hung by means of Elliot locked-coil ropes attached to steam-capstans. The water now began to leave No. 1 pit and had to be pumped through the tunnel to the Hathorn-Davey, Pearns and Evans pumps.

The greatest difficulty now was not with the pulsometer-pumps but with the suction-pipes, which were of light cast-iron, and having this large quantity of water the workmen were obliged to fire the shots while the suction-pipe was actually in the pit-bottom. As many as three or four suction-pipes were broken in a week, and after considerable thought, a flexible joint was made something after the fashion of a short length of large fire-hose (Figs. 1 and 2, Plate XIX.). The flexible joint was connected with the pumps

above and the continuation of the suction-pipe below, and provided the needful elasticity, thus avoiding breakages from sudden shocks by shots. This joint has been an eminent success, and the writer strongly recommends its use in any kind of sinking operations.

The ordinary delivery and suction-clacks did not give satisfaction, as they required too frequent renewal. Disc-valves of rubber were used, and proved most successful.

Sinking was continued until March 27th, 1897, when a depth of 414 feet was reached, and during the whole of this time fresh feeders were being constantly tapped, but the feeders above either became less or followed the pit down. The water being pumped at this time was about 120,000 gallons per hour, practically all in No. 2 shaft. As each large feeder was reached, water-rings were inserted, and although they had 12 inches flanges with 7 inches waterways, and as many as six outlets in them, they were insufficient to take away the water.

The writer may here refer to the great importance of making the water-rings thoroughly watertight, otherwise it is of no use putting them in. The best way is to lay them on oakum, and set the first six courses of bricks in cement and mortar; then grout the whole in with very good and fresh cement, and then there will be no difficulty in making them tight. In no instance has water passed any of the water-rings, although they have been put in with feeders flowing over them of 60,000 and 70,000 gallons per hour.

The pit has always been dry, and this is a very great advantage in every way. Many engineers prefer to bed the water-rings in clay and to puddle them, but the body of clay that can be inserted is so small that it perishes, and consequently fails in its object. Two of the first water-rings inserted in No. 1 shaft were laid in this way, and although there was only a very small quantity of water near them, in both cases the water passed them. All the water-rings were laid on solid beds, 18 inches wide, and 18 inches brickwork was built for about 3 feet above each ring, and as the next length of brickwork came up from below the rock was cut out, and thus 9 inches of brickwork was built under the front edge of the ring. When this can be done, it is a much better way than carrying the water-ring on plugs.

On April 2nd, 1897, another feeder was found; the two pulsometer-pumps already in the shaft were stationed at that point and tanks made of light steel plates were used to catch the water

met with down to this point, and it was pumped by the two pulsometer-pumps. Two more pulsometer-pumps were applied and fixed on the ropes.

Keeping the bore-hole about 12 feet in advance, the sinking proceeded to a depth of 438 feet comparatively dry, until on April 18th, 1897, a further large feeder was tapped by the bore-hole at a depth of 450 feet. The water rushed up the bore-hole and rose like a fountain to a height of 26 feet above the top of the hole, which was immediately plugged. It was decided to put in another Pearns pump capable of delivering 70,000 gallons per hour to the surface, this was located in an engine-house, and started pumping on August 8th, 1897. In the meantime, ten or twelve holes had been bored down to the feeder, and the volume ascertained to be 90,000 gallons per hour. The pumping of this feeder was continued, leaving the holes open while the Pearns pump was being fixed. Men were kept ready to plug the holes, in case of any mishap to the pumps, and when sinking was resumed the pressure was so far reduced that the water only rose about 8 feet above the tops of the bore-holes.

One bore-hole was put down to a depth of 68 feet below the feeder, and into the Coal-measures, so that this large feeder was issuing where the Red Sandstone joined the Coal-measures. It was recognised that this point was below the water-bearing strata, and it was at once decided to catch the water, as there was ample pumping power to deal with it.

On August 13th, 1897, sinking through this feeder was commenced and at a depth of 456 feet a sealing-ring was inserted to enable us to take or stop the water at will, and it was completed and the scaffold removed from No. 2 pit on September 11th, 1897.

After this, sinking was continued with water in the bottom until a depth of 468 feet was reached, where tanks were put in, and the water allowed to pass from behind the tubbing, through pipes, 12 inches in diameter, and valves that could be regulated. These valves were frequently closed for 12 hours, and the water caused no trouble. This arrangement was completed by the end of September, 1897.

Afterwards, the sinking was comparatively free from difficulty, as all the water was effectually caught, there was none in the pit-bottom or loose in the shaft, and it was all being pumped from

behind the tubbing or out of tanks. The quantity, during September, 1897, being pumped to the surface varied from 160,000 to 170,000 gallons per hour. This maximum quantity has gone on diminishing, so that at the present time (February, 1899) the engines are not pumping more than 70,000 gallons per hour, and the writer is even hopeful that there will be a further substantial diminution.

No. 2 shaft is now completed, it has passed through the Wigan 6 feet mine, and is 64½ feet below it, and the coal-field is now being proved. The total depth of this shaft is 1,812 feet. The celebrated Abram cannel was found at a depth of 1,686 feet, of excellent quality, 6 feet 3 inches thick, with 1 foot 7 inches of coal on the top of the cannel. The whole of the mines passed through are above the average thickness and of good quality.

The writer thinks it would be well in this portion of his remarks to give the members the benefit of the experience which he has gained from this work. There is an advantage in all important undertakings, that circumstances arise during the carrying out of the work, which, if properly appreciated, may be very useful in future undertakings of a similar character.

It will hardly be necessary for the writer to tell an audience composed of those who have charge of important mining works, that there should be no scamping in mining-appliances, and that, especially in sinking-operations, everything should be made of the best material. This requirement should be placed first and foremost in the interests of safety, because no amount of skill and care can prevent serious accidents if the appliances be defective. Everything that has to be used in sinking should be of the best quality, and so far as possible everything should be tested to a very much higher stress than it is intended to bear.

Not only should everything that has to be used in the way of lifting have a large margin for safety, but the whole of the pumping-plant should be equal to at least double the work which it will be called upon to perform. It will have been noticed that the greatest volume of water was 170,000 gallons an hour, and it has been satisfactory to the writer to know that the pumping-appliances at his command were nearly equal to double that amount, namely, 310,000 gallons per hour from a depth of 360 feet.

So far as practicable everything should be provided in

duplicate, some of the most important desiderata being:—(1) There should certainly be two independent steam-pipes to the pumps as a blown-out joint in a large range of steam-pipes might lose the pit; (2) duplicate boiler feed-pumps; (3) duplicate pumps to the condensers of the pumping-engines; and (4) it is very important to have valves at the surface to each set of steam-pipes going to the pumps in the shafts, with signalling appliances, so that they can be closed immediately in case of accident.

It is simply throwing money away to construct shafts, which in any case entail an outlay of many thousands of pounds, with defective material. The brickwork should all be built in solid, and set in good mortar. Where water has to be contended with, the setting should be made with Lias lime. In no case should there be any backing to the brickwork, the writer's experience being that such constructions always lead to trouble by the brickwork giving way; and, above all, only good hard-burnt bricks should be used.

The improvements in steel-manufacture of recent years have greatly assisted important mining undertakings, and engineers are now able to make use of steel which, with a quarter of the weight, affords greater strength than the cast-iron that formerly prevailed. The advantages of diminishing the weight to such an extent will be readily understood. When both pumps and pipes are slung from the surface, and raised and lowered daily, engineers will understand how necessary it is that they should be both light and strong, and the pipes should be fitted with joints that can be easily made, and are not liable to give way.

All the pumping-appliances named, with the exception of the Hathorn-Davey pumping-engine on the surface, were not intended as permanent plant. Most sinking-pumps are not economical in the use of steam, and when permanent plant is erected, as far as possible, only the most economical should be adopted. The writer may remark, that in sinking, economy is not always the most important matter to consider, as the best kind of pump is one that will go the longest time without stopping, for at times stopping pumps with 2,500 gallons of water per minute in the pit, means disaster.

The Evans straight-line sinking pump did good service, it is strong and wants little repairs, the clacks are adapted to pump any amount of sand, and it is a ram-pump. Nothing but a ram-

pump would have been of any use owing to the sand, which was raised with the water. The various pumps at times have dealt with several tons of sand every 24 hours. The Pearns horizontal duplex pump, with a short stroke running quickly, is suitable for pumping large quantities of sand. The Evans and Pearns pumps were frequently run at 35 strokes per minute. The Pearns pump had valves that would also pass any amount of sand. Neither of these pumps wanted repairing very often, and this is a great consideration. The writer only agreed to use the pulsometer-pump with a guarantee, which has been more than fulfilled. By the vital principle of its action this pump is light, which enables it to be easily handled, and as the steam used in forcing the water combines with and is delivered with the water, all trouble from exhaust-steam in the shaft is avoided.

The writer does not hesitate to state that if he had to commence another sinking of this character, to pass through a volume of water of 150,000 gallons an hour at a depth not exceeding 300 feet, he would use pulsometer-pumps alone for the pumping during sinking. He is satisfied, with the pressure of steam now easily available, that pulsometer-pumps would raise practically any volume of water to a vertical height approaching 100 feet, which would necessitate the use say, of three different pulsometer-pumps and different lifts for that depth. He would make his shafts large enough in diameter to provide room for these pulsometer-pumps without interfering with the needful area in the shaft itself. A pulsometer-pump will pump almost anything, and matter with which an ordinary pump finds it impossible to deal does not hamper a pulsometer-pump. One pulsometer-pump was pumping 30,000 gallons per hour against a head of 107 feet, with a steam-pressure of 85 pounds per square inch for many months.

The writer has already expressed his opinion that whatever class of pumping-appliances is in use, each separate pump should have a man constantly in charge. When pumps stop they take some time to re-start, and a man having hold of the steam-valve can often prevent a pump from actual stoppage. If the work goes on smoothly he has little or nothing to do—so much the better—but in the event of the mishaps so natural in sinking operations, the man is in attendance, and can prevent a disaster which might flood the shaft. The writer is also of opinion that in no case should pumps be left to the mercy of sinkers.

The writer will now briefly describe the method adopted when reaching the bottom-feeder, which was the largest feeder encountered, making 90,000 gallons per hour. Below the sandstone was hard white rock for some depth, and 8 feet above the feeder, the shaft was widened out 2 feet 6 inches all round, and the shaft was sunk of this diameter down to 6 feet below the feeder. There was a perfect bed for a bricking-ring, made of cast-iron in eight segments, with a flange, 6 inches high, at the front, and another flange of the same size, 19 inches from the front. This ring was laid on strong felt and carefully grouted with cement. When this ring was made tight, a cylinder was made of boiler-plates, 15 feet high, in two parts, the bottom part being 10 feet and the top part 5 feet long. The cylinder was also in eight segments, each segment having $2\frac{1}{2}$ inches angle-iron rivetted to it, with $\frac{3}{4}$ inch holes, spaced $2\frac{1}{2}$ inches apart, for bolting the sections together, and an angle-iron ring rivetted to the bottom, for the cylinder to stand on; with rings of 4 inches angle-iron, having $\frac{3}{4}$ inch bolts, spaced $2\frac{1}{2}$ inches apart, for bolting the upper and lower lengths together. The 10 feet length was put in first, with two 12 inches outlet-pipes near the bottom, and two other outlets, 7 feet from the bottom, fitted with $12\frac{1}{2}$ inches delivery-pipes, 2 feet long. These segments were bolted together, with indiarubber strips at the joints, and caulked with oakum at the bottom behind the flange on the ring and made perfectly watertight. A ring of 18 inches cement brickwork was built up to the top of the 10 feet cylinder, and each course grouted with cement, then two blank flanges were put on the bottom pipes, and the water flowed out of the top pipes. The 10 inches space behind the boiler-plate cylinder was then filled with concrete made of small broken bricks and cement. As each foot in height was filled, cement was run down through 4 inches pipes, with funnels at the top, so that it would run all round. When this was filled to a height of 6 feet, the next 3 feet was filled with broken bricks—about three pieces out of each brick. Some old boiler-plate was then placed on the top of these bricks, and made tight with cement and concrete to the top of the 10 feet cylinder. The 5 feet cylinder was then built on the top, and bolted together to the lower cylinder with indiarubber strips between the horizontal joint and the vertical joints, and the 18 inches cement brickwork was carried to the top of this cylinder. The top length was filled with concrete in the same way as the bottom length, and the brickwork

The Institution of Mining Engineers.
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To illustrate Mr. James Keens "Description of the Sinking of Two Shafts" etc.

Vol. XIX, Plate XIX.

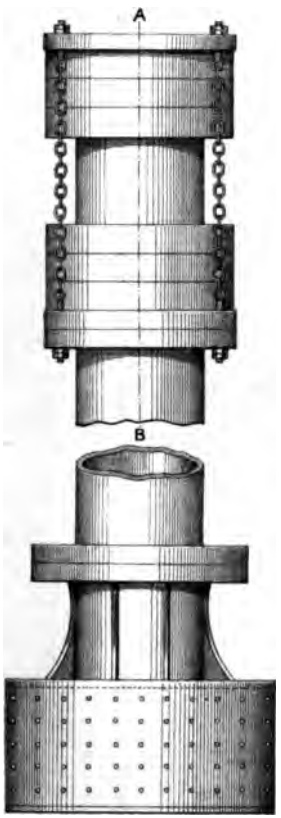

FIG. 1.

Scale, 1½ Feet to 1 Inch.

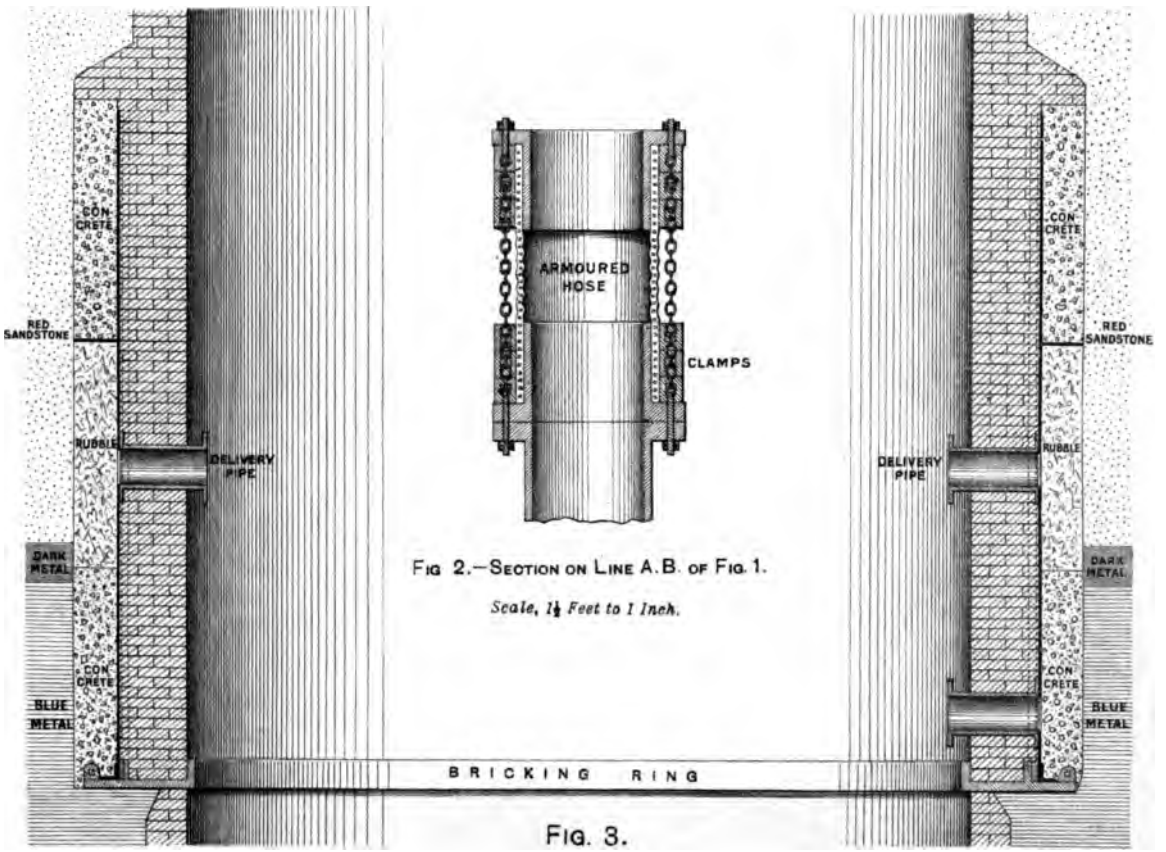

FIG 2.—SECTION ON LINE A.B. OF FIG. 1.

Scale, 1½ Feet to 1 Inch.

FIG. 3.

Scale, 4½ Feet to 1 Inch.

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Transactions 1899 1900.

And.r Reid & Comp.y Ltd. Newcastle on Tyne.

Vol. XVI, Plate V.

was carried up to the ring above it. Valves were put upon the delivery-pipes, which, when the pumps are at work, are kept open, and when from any cause the pumps are stopped these valves are closed, and the shaft is kept perfectly dry (Fig. 3, Plate XIX.).

The diameter of No. 1 pit is 18 feet and of No. 2 pit, 16 feet.

Such is the writer's description of the sinkings at Maypole so far as they have progressed, and as they mean not only the passing through of the whole of the watery strata, but that in No. 2 shaft a further distance of 600 feet has been accomplished, he thinks that the description almost covers the entire work.

Mr. JAMES KEEN said that two Pearns pumps were being erected, 12 inches in diameter and 3 feet stroke, to pump 80,000 gallons of water an hour when running at an easy speed. The lodge-room was 75 feet below the water, and in addition, there were two independent pumps, either of them capable of raising a large volume of water. The engine-house would be 80 feet long by 15 feet wide, and 15 feet high.

Mr. G. B. WALKER asked whether the pulsometer-pump used 50 per cent. more steam than an efficient pump to raise the same quantity of water.

Mr. JAMES KEEN replied that he could not give the exact steam-consumption. One difficulty with the pulsometer-pump was that if it was so unfortunate as to stop, it would take ½ hour to re-start it. An engineman of experience could tell when the pump was going to stop: if the ball began to chatter, he should shut off the steam until it steadied again; when left to themselves these pumps stopped constantly.

Mr. WALTER HARGREAVES said that Mr. Keen's arrangement of a flexible joint on the suction-pipe was useful, and it would reduce the breakage of strainers and suction-pipes while firing shots in the pit-bottom. The valves of pulsometer-pumps were destroyed in considerable numbers.

Mr. JAMES KEEN stated that if the valves were made as described in his paper, they would require less frequent renewal.

The pulsometer-pump was worked with a sliding steam-joint, 8 feet long, and the joint was packed like a piston-ring, in order that it could be slid back.

Mr. M. H. HABERSHON asked how the cement was inserted after the water-rings had been laid, while such large volumes of water were flowing over them.

Mr. JAMES KEEN stated that the water-rings were laid on oakum, after the bed had been carefully levelled, and then the cement was run in. They then laid three or four courses of bricks on the ring, leaving pigeon-holes to allow the water to flow into the water-pipe ring.

Mr. M. H. HABERSHON asked what was the composition of the cement.

Mr. KEEN replied that Portland cement was used. When large volumes of water were flowing, a temporary wooden ring was used, which caught the bulk of the water and passed it into the middle of the pit until the cement was set.

The PRESIDENT (Mr. W. H. Chambers) moved a vote of thanks to Mr. Keen for his valuable paper.

The motion was unanimously adopted.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

THE FORMATION OF COAL.

Sur les Marais Tourbeux aux Epoques Primaires. *By* B. RENAULT. *Bulletin du Muséum d'Histoire Naturelle*, 1900, *pages* 44, 48 *and* 202, *with figures in the text.*

In this paper, dealing with the peaty marshes of Palæozoic times, the author points out, first of all, that the fermentation of plant-remains at that remote epoch did not necessarily result in the formation of coal. He refers in this connection to the remarkable layer of fossil charcoal at Tovarkowo in the Lower Culm of the Moscow basin; this is entirely made up of cuticles belonging to *Bothrodendron*-stems interpenetrated with ulmic acid. No part of the cellular, ligneous, or cortical tissues of those arborescent Lycopodiaceæ has been in this instance converted into coal, despite the enormous number of Bacteriaceæ still found adhering to the more or less corroded cuticles.

Some of the Palæozoic marshes were invaded by siliceous waters which, petrifying the plants in various stages of decomposition, preserved them in the state (structurally) in which they were at the time of the inflow. This was of frequent occurrence in what are now the coal-fields of Autun, St. Etienne, etc. So the author figures, for comparison, microscopic sections of Palæozoic silicified peat and recent peat. The resemblance is striking; the minute state of division of the vegetable organisms in both cases is the result of the action of microbes on membranes which are common to ancient and to recent plants. It is true that in the silicified peat some débris are altered into a black, often opaque, substance similar to coal. This is explicable, if it be remembered that on the plants in the ancient marshes settled vast hordes of various Bacteriaceæ, some of which broke down the plant-tissues without producing coal, while the action of others gave rise to its production.

It seems probable that the coal-producing Bacteriaceæ were scarce in, or entirely absent from, the shallow lakes or swamps rich in ulmic matter wherein the boghead and the cannel of the Moscow basin were formed and the Tovarkowo cuticles were accumulated; these lay in the heart of a continent but little exposed to denuding agencies. The coastal marshes on the other hand, the trackless swamps of the great river-deltas, wherein the coal-producing Bacteriaceæ would develop, were exposed to frequent floods; and plant-remains (in a more or less minute state of division) were swept out into lakes and estuaries, where the anærobic (non-air breathing) Bacteriaceæ, favoured doubtless by deeper waters, completed the conversion into coal. With this sequence of events, moreover, is connected the frequent occlusion within the mass of the coal of methane (or marsh gas) and carbon dioxide.

As a proof that such plant-remains lay for a time in swamps before they were swept out into the lakes and estuaries, the author figures a completely carbonized fossil wood, containing the mycelia of saprophytous fungi analogous to those which occur in the wood found in peat-bogs.

The author appends a short note confirming the foregoing conclusions, and erecting two new species of bacteria: *Bacillus colletus* and *Streptothryx anthracis*, which occur in "coalified wood," as he terms it. L. L. B.

FOSSIL SEA-WATER IN THE COAL-MEASURES.

Salzwasser im Carbon. *By* DR. CARL OCHSENIUS. *Zeitschrift für Praktische Geologie*, 1901, vol. ix., *pages* 19-20.

The author aims chiefly at controverting the general spirit of the conclusions arrived at by Prof. Gosselet, in his paper on saline waters in the Carboniferous and other strata of Northern France (read before the Eighth International Geological Congress held at Paris in August 1900). Prof. Gosselet appealed to the evidence of level, as destructive of the hypothesis of the origin of such waters by infiltration from ancient or modern seas.

The present author begins by pointing out that nearly all the salt that exists is primarily derived from the sea, even going as far back as the boiling-hot oceans of the Laplace theory. There are plenty of saline waters on the face of the globe far above sea-level, many of them of very recent origin. The enormous rock-salt deposits in the Andes lose some of their mass by solution, and the briny waters percolate downwards into lower beds.

Referring to the presence of borate of soda in the coal of the Ferrouillet colliery, Belgium, the author notes that when in a typical barred gulf (or such an one as that of Kara Bugas) the evaporating sea-water deposits gypsum and rock-salt, the mother-liquors which remain contain borates. Even if these waters sometimes regain access to the ocean, they leave pools in the hollows of the anhydrite crust of the barred gulf, and ultimately the contents of these pools percolate through the underlying rocks. Borates may thus, in places, so strongly impregnate the soil that the plants which do contrive to vegetate there, perforce take up boracic salts in their tissues. So, if, in Coal-measure times, the plants found in the strata of the Ferrouillet colliery had grown on soil which was the site of a mother-liquor pool such as those described, the ligneous tissues became necessarily filled with boracic salts. Nor did the driftwood give these salts up as it floated out into the Coal-measure lake or lagoon, and sank later to the bottom to slowly carbonize into coal.

L. L. B.

SEISMOGRAPHIC INSTRUMENTS AND ATMOSPHERIC PERTURBATIONS.

Gli Strumenti Sismici e le Perturbazioni Atmosferiche. *By* G. AGAMENNONE. *Atti della Reale Accademia dei Lincei, series* 5, *Rendiconti*, 1900, *vol. ix.*, *pages* 308-313.

The author had long been persuaded that the tromometer or seismographic pendulum is considerably affected by whatever wind happens to be prevailing. He compared during five months the mean diurnal motions of the tromometer with the mean velocities of the wind at the observatories of Catania, Mineo, Rocca di Papa, Florence and Spinea di Mestre, and the conviction thus attained was confirmed by his own experience from August, 1899, onwards.

From that date, he has been director of the Geodynamic Observatory at Rocca di Papa, and has made continuous observations on the tromometers erected there by the late Prof. Etienne de Rossi. These, although suspended to the central shaft of the seismic-pillar, which is based on the live rock and quite independent of the walls of the building, are undoubtedly affected by the wind. In the case too of some electric-contact tromometers, when the weather turns bad, the author finds it advisable to diminish their sensitiveness by increasing the distance between the platinum contacts.

On June 10th, 1900, a thunderbolt fell on the house occupied by the observatory officials at Rocca di Papa, and the effect of the electric discharge was registered by various seismographic instruments:—the Agamennone seismoscope and photochronograph, the Brassart seismometrograph, and the horizontal pendulum.

The author remarks on the enormous progress made of late years, in point of delicacy and accuracy, in the manufacture of seismographic instruments, and appears to believe that the tromometer has definitely lost the supreme position which it once occupied among such instruments.

L. L. B.

THE NATURE OF EARTH-WAVES.

Sur la Nature des Vibrations Sismiques. *By* P. RUDZKI. *Bollettino della Società Sismologica Italiana*, 1900, *vol. vi.*, 4 *pages.*

The author does not believe in the existence of the supposed distinction between longitudinal and transverse earth-waves, or in other words, between waves of dilatation and waves of torsion. The distinction, valid though it be in the case of an isotropic elastic medium, cannot be postulated of so essentially anisotropic a medium as that formed by the various rocks which go to make up the earth's crust. Further, although nothing positive is known as to the physical constitution of the deeper-lying mass, all the probabilities are against its possessing the same elasticity in every direction. This leads to the conclusion that seismic undulations are neither purely dilatational nor purely torsional, and that the vibrations are neither exclusively longitudinal nor exclusively transverse. L. L. B.

EARTHQUAKES IN THE VOGTLAND, PRUSSIAN SAXONY.

Die Vogtländischen Erdbebenschwärme während des Juli und des August, 1900. *By* HERMANN CREDNER. *Sitzungsberichte der Königlich Sächsischen Gesellschaft der Wissenschaften, Leipzig*, 1900, *pages* 155-177, *with a table and* 4 *maps.*

The Vogtland is known as a district chronically afflicted with earth-tremors, and in the autumn of 1897 shocks were recorded there for 37 consecutive days. But this record was eclipsed in the summer of 1900; a period of earth-tremors began on July 1st, and terminated only on August 21st, or 52 days in all. It is true that none of the shocks observed last year were as violent as the most considerable shocks of 1897, and the area of seismic activity was correspondingly less extensive.

The 52 days period is really made up of two distinct periods, separated by a pause in the tremors of about 7 days (from July 11th to July 18th). In each case there was a kind of prologue of subterranean muttering and rumbling, followed by a series of shocks increasing daily in number and varying in violence until they culminated in one or two maximum shocks.

Thenceforward the tremors decreased more or less fitfully, and the close of the earthquake period was marked by a slight shock with an accompaniment of subterranean rumbling. These tremors were traced to two different *foci*, about 12 miles apart: the most pronounced of the two proved to be the Graslitz-Eibenberg-Untersachsenberg area, in the south-east of the Vogtland (it had been the epicentrum of the greatest shocks in 1897). The less pronounced epicentrum lies in the extreme southern corner of the Vogtland, in the area between Brambach-Schönberg and Asch. On former occasions these two centres of seismic phenomena did not show coincidence of activity; for twenty years before 1897, for instance, there were numerous local earthquakes in and about Brambach, while the remainder of the Vogtland was undisturbed. In 1900, however, so soon as the shocks starting from the Graslitz epicentrum had reached their maximum intensity, they appeared to induce the Brambach epicentrum to give rise to concurrent vibrations. For a time the two areas appeared to merge their tremors in one, recurring later on to their pristine independent seismicity.

To a similar circumstance may be attributed the curious sporadic shocks and subterranean noises recorded at certain peripheral, outlying localities not included within the isoseismal areas. It is evident that during the whole period of tremors the effect of the seismic activity was, at localities tectonically predisposed thereto, in a region so split up by fissures and faults as the Vogtland, to induce underground "settling and sagging" of the strata, thus giving rise to what may be termed "relay-" or accessory earthquakes.

The very useful table at the end of the paper summarizes all the important data collected in regard to the Vogtland earth-tremors of 1900.

L. L. B.

THE EARTHQUAKES OF TRIPOLIS AND TRIPHYLIA, GREECE.

Die Erdbeben von Tripolis und Triphylia in den Jahren 1898 *und* 1899. *By* Prof. C. Mitzopulos. *Petermanns Mittheilungen*, 1900, *vol. xlvi., pages* 277-284, *with plans in the text.*

With respect to the Tripolis earthquake, which took place on June 2nd, 1898, the author's investigations have convinced him that it was due to subterranean landslides, caused by the falling-in of the caverns which are eaten out by underground waters in the limestones of which the district consists. The shock travelled to Rome at the rate of 2,580 feet per second, but to Zante only at the rate of 870 feet per second; and this diminished speed is perhaps attributable to the great depth of sea (1,600 feet) between Tripolis and Zante.

Triphylia, a fertile province stretching along the western coast of Peloponnesus, belongs to a region which has frequently been devastated by earthquakes, and the shock of 1899 was really a continuation, a sort of dying spasm, of the great catastrophe of 1886. Many villages were completely destroyed, though fortunately without loss of life. On January 22nd, 1899, on a fine winter's day, at 9·53 a.m., two very strong undulatory shocks were felt at Kyparissia, travelling from south-west to north-east, lasting each about 15 seconds, and setting the church-bells ringing. Between that time and the evening, 16 more shocks took place. After-shocks went on until February 12th. It is noticeable that buildings whose foundations are laid on solid rock have not suffered so much as those built on the comparatively

loose Tertiary beds. This is further well shown on the author's geological map of the region; the destructive effects of the earthquake are seen to be practically confined to the areas of newer, looser-textured strata (Neogene), while the older limestone and hornstone areas are unaffected. All the indications point to the epicentrum of the earthquake as being situated in the Ionian Sea, about 25 miles off the Peloponnesian coast, and the central focus was about 45 miles below the sea-bottom (calculating according to Mallet's method). The velocity of travel of the earth-tremors as far as Rome is reckoned at 3,786 feet per second. L. L. B.

THE GREAT EARTHQUAKE IN NORTHERN HONSHU, JAPAN.

Das grosse Japanische Erdbeben im Nördlichen Honshū am 31 *August*, 1896. *By* Dr. N. Yamasaki. *Petermanns Mittheilungen*, 1900, *vol. xlvi., pages* 249-255, *with diagrams in the text and* 1 *map.*

It was in June, 1896, that the great tidal wave wrought disaster on the Kitakami coast in northern Japan, sweeping into eternity 22,000 human beings. A bare 2 months after this appalling catastrophe, on the afternoon of August 31st, 1896, a violent earthquake laid waste the provinces of Rikushu, Uzen, Ugo and Mutsu, and 1,000 persons suffered in life or limb. The author was sent by the earthquake committee of the Imperial Japanese Government to investigate the occurrence in detail, and the memoir now published embodies the results of this investigation.

The first gives a brief topographical and geological description of the epicentral region, and a full table of times and intensities of the shocks recorded from various localities. He remarks that preliminary shocks are not usually felt in Japan in the case of a great earthquake, but in this instance there were premonitory shocks on August 23rd, and slight tremors continued for several days thereafter up to the moment of the principal earthquake; the warning thus conveyed accounts for the comparatively small loss of life.

Magnetic disturbances were recorded from midnight of August 29th, onward, reaching their maximum about 33 hours before the great shock. After-shocks were very numerous: thus, at Morioka, about 19 miles from the eastern fissure, 149 shocks were counted within 37 hours following on the principal earthquake. At Akita, 28 miles distant from the great fissure at Rokugo, 146 after-shocks were counted within a fortnight.

The originating cause of the earthquake has been traced by the author to two long lines of fracture which run parallel, one on either side of the main axis of the central mountain-range of Japan; the outer walls of these fractures were found to have sunk by several feet. To the eastern fissure the author applies the name of the Kawafune fissure, and to the western that of the Senya fissure; the former is about 9½ miles long, the latter as much as 37 miles long. Now, in 1894, a disastrous earthquake took place in northern Japan, which was traced back to a line of dislocation known as the Yadaresawa fault; there is no doubt about the existence of a close relationship between this older dislocation and the Senya fissure—in point of fact, the latter turns out to be a prolongation of the former.

The Honshu earthquake of 1896 corresponded (in the Akita and Iwate districts) to an intensity of 8 to 10 in the De Rossi-Forel scale. The farthest place at which shocks were felt was Sakai, near Matsue, on the Japanese

Sea, about 500 miles south-west of the epicentrum, but the tremors were registered by the Rebeur horizontal pendulum as far away as Strasburg in Alsace, and Rome, Rocca di Papa, Ischia and Catania.

Besides opening up the great fissures, the earthquake caused several landslides; valleys were bestrewn with fallen rock-masses and dammed up streams were turned into lakelets. As usual, the seismic disturbance was greater in the lowland plains than on the flat plateaux. In various localities in the plains, the sand and mud mixed with water squeezed out of small fissures, has formed little conical hillocks. Some thermal springs diminished in volume or ceased entirely, while at Sengantoge, a new spring made its appearance. L. L. B.

CHROME IRON-ORE OF KRAUBAT, UPPER STYRIA.

Beitrag zur Genesis der Chromeisenerzlagerstätte bei Kraubat in Obersteiermark. *By* Dr. Franz Ryba. *Zeitschrift für Praktische Geologie*, 1900, *vol. viii., pages* 337-341, *with figures in the text.*

This paper is mainly concerned with the confirmation of Prof. Vogt's hypothesis, based on the observations made by him in the Hestmandö and Röros chromite-mines of Norway, that the chrome iron-ore which occurs in eruptive peridotites or in the serpentines derived from them is a primary product of magmatic differentiation.

The Kraubat ore occurs in a rock whose principal constituents are olivine and chromite, and the rock is therefore properly a dunite. One of the author's colleagues at the Mining School of Pribram made a chemical analysis of the ore showing that it is not an absolutely pure chromate of iron ($FeCr_2O_4$), the percentages are: Silica, 4·3; magnesia, 9·7; cobalt oxide, 6·4; ferrous oxide, 9·1; alumina, 13·7; and chromium sesquioxide, 56·2. The chrome iron-ore is scattered about irregularly in the dunite, generally in the form of more or less rounded octahedra. L. L. B.

IRON-ORE DEPOSITS OF THE STUBAI VALLEY, TYROL.

Ueber ein Eisenerz-Vorkommen im Stubaithale. *By* J. Blaas. *Zeitschrift für Praktische Geologie*, 1900, *vol. viii., pages* 369-370, *with a section in the text.*

Along the line of the Brenner, Triassic dolomites and limestones are seen to overlie unconformably the folded mica-schists of the Stubaierstock: they really fill an old basin eroded in the schists, and at the base of the dolomites occur frequently bands of conglomerate, sandstone and quartzite, sometimes so highly charged with iron that they would repay working. An attempt was made so long ago as 1831, but the difficulties of transport appear to have been the determining cause of the abandonment of the enterprise: now, however, that a light railway is about to be constructed from Innsbruck into the Stubai valley, the economic conditions are more favourable.

The author states that experimental diggings have exposed quartzite richly impregnated with specular iron (60 per cent.) and magnetite in grains and crystals. He estimates the average thickness of the ore-deposit at 12 or 13 feet, but is unable to give reliable statistics as to its extent along the strike, although the fact that it has been found at several points pretty far apart seems to indicate that the extent is considerable. The ore-bearing quartzite revealed by the old adit, which has been carried only some 20 feet into the mountain-side, is not so rich as that above described. The quality of the ore is said to be excellent, and even if it were carried no farther it could be used in the ironworks of the neighbouring town of Vulpmes. L. L. B.

ANTHRACITE IN NASSAU HÆMATITE, GERMANY.

Vorkommen von Anthracit in Nassauischem Rotheisenstein. *By* L. Loewe. *Zeitschrift für Praktische Geologie*, 1900, *vol. viii., pag.* 341-342.

In the Devonian hæmatite worked in the iron-mines of the neighbourhood of Dillenburg, anthracitic inclusions occur over a length of about 1,800 feet. They are dispersed equally through the mass in the direction of the dip, from the outcrop at day down to the lowest depth yet reached in the mines (390 feet). Such inclusions are especially numerous in the Königszug and Stillingseisenzug mines. In some cases, they occur in very thin black strips, which frequently pass into a carbonaceous impregnation of the hæmatite, so as to blacken completely great masses of ore. In other cases, the inclusions are closely packed together in lenticles, measuring up to 8 inches in length and 2 inches in thickness. As a rule, such nests pass gradually into the neighbouring rock, the ironstone being merely sprinkled along its edge with fine anthracitic particles: the concentration of these little by little into masses of perfectly pure anthracite can be traced uninterruptedly. Sometimes, however, the anthracite ends off sharply against the hæmatite, a thin film of iron-pyrites often marking the boundary between the two. The anthracite exhibits the usual characters: deep black hue, strong metallic lustre, and greyish-black streak.

In discussing the origin of this occurrence, the author lays down the preliminary postulate that all anthracite was formed in the wet way. As these Nassau hæmatites are truly bedded deposits, though probably of a metasomatic character, it may be assumed that the ferruginous waters which altered the original limestone-beds into red ironstone, held in suspension organic substances which were precipitated with the iron, and by slow decomposition ultimately became anthracite. L. L. B.

THE KAOLIN-DEPOSITS NEAR LA SPEZIA, ITALY.

Il Caolino dei Dintorni della Spezia. *By* E. Sallé. *Atti della Società Toscana di Scienze Naturali, Processi Verbali*, 1900, *vol. xii., pages* 103-106.

Up till about two years ago, the true character of the kaolin-deposits, which occur at various localities in the hills around La Spezia, was not known. The *terra bianca* (white earth), as it is locally called, was thought to be calcareous, and was indeed mistaken for chalk. An expert who chanced to pass through the village of Montenero in 1898, examined the mineral, and after careful scrutiny pronounced it to be kaolin. Various trials having proved its industrial value, workings were started with feverish alacrity. Despite the checks and disappointments which inevitably wait on exaggerated hopes, the Montenero workings are now very flourishing.

A landowner of Corvara, near Il Pignone, finding on his property white earth similar to that of Montenero, had it analysed, and it proved to be kaolin of excellent quality, but so far workings have not been started at the new locality.

The author's researches tend to show that this kaolin is an alteration-product of euphotide (diallage-felspar-rock). Below the euphotides, in the Spezia district, come dark green serpentinous rocks, and where the latter are superficially altered, the presence of steatite, asbestos, and (less abundantly) malachite, is noted. The percentage composition of the Corvara kaolin is as follows: Silica, 48·65; alumina, 35·20; lime, 2·79; magnesia, 0·65; water, 11·30; oxide of iron and alkalies (determined by difference) 1·41.

L. L. B.

THE ORIGIN OF THE CINNABAR AND ANTIMONY-ORE DEPOSITS OF TUSCANY.

Die Zinnober und Antimon führenden Lagerstätten Toscanas und ihre Beziehungen zu den Quartären Eruptivgesteinen. By DR. B. LOTTI. *Zeitschrift für Praktische Geologie*, 1901, *vol. ix., pages* 41-46.

The author begins by pointing out that there have been in Tuscany three great periods of ore-deposition: firstly, in Eocene times, when, in connection with the eruption of serpentine-rocks, copper-ores, and almost exclusively copper-ores, were deposited. Secondly, in the Miocene age, when iron-ores, large cupriferous quartz-veins, calamine, and miscellaneous sulphides were formed, in connection with the eruption of acidic (especially granitic and porphyric) rocks, as in Elba, Giglio, near Caverano, and Campiglia. Lastly, in earliest Quaternary times, when as a consequence of the outburst of trachytic and andesitic lavas of Monte Amiata, Roccastrada, Monte Catini in Val di Cecina, and Orciatico, sulphides, almost exclusively of mercury and antimony, were formed. With these later phenomena may be associated the recent occurrences of thermal springs, deposition of travertine, and evolution of sulphuretted hydrogen.

The main object of the present memoir is to prove the genetic relationship existing between the eruptive phenomena of the third period and the mercury-antimony ore-deposition.

First of all, in regard to Monte Amiata, the cinnabar occurs in rocks of the most various texture, origin and age: in Middle Liassic limestones, in Upper Liassic limestones and quartz-schists; in Nummulitic Limestone; in Eocene sandstones and shales; and finally in the trachyte itself. The warm sulphur-springs and the emanations of gas at Abbadia San Salvatore and other ore-bearing localities are shown to coincide with a great subterranean fissure, along which the Eocene strata are faulted against the older Mesozoic rocks of Monte Zoccolino. It is plain that the cinnabar was introduced into so many different rocks of various ages by means of percolating solutions which, on the limestones and sandstones, had a more or less corrosive action.

There is an intimate relationship between the mercury and the antimony-ores of the region here dealt with. In the Monte Amiata district and the Maremma Grossetana, the two ores frequently occur in association in the same deposit. One ore-body which was long worked, and proved to be the purest and richest in Tuscany, occurred in an enormous mass of compact quartz, the hanging-wall of which is Eocene limestone and the foot-wall Permian. Here besides antimony-glance are traces of realgar. A similar association of *putizze* (sulphuretted-hydrogen blowers) and thermal springs is noted in regard to the antimony-ore deposits, as in regard to those of cinnabar.

At Jano, in Volterra, cinnabar occurs both in rocks of Carboniferous age and in the pyritous Pliocene clays against which the Palæozoic rocks are faulted. L. L. B.

PYRITES-DEPOSITS IN NORWAY.

Kisforekomster langs den Projekterede Sell-Storen-jernbane. By E. GULLIKSEN *and* PROF. J. H. L. VOGT. *Teknisk Ugeblad*, 1899, *vol. xvii., pages* 427-430, 444-447, 465-469, 475-477, *and* 487-488, *with figures in the text.*

The Sell and Storen railway is projected to open out the country south of Trondhjem (Drontheim), in the heart of Norway, Sell being about 120 miles south-south-west of that place as the crow flies, and 90 miles from Storen,

where the new line joins the existing railway. Short branches running to the west might connect the line with the coast in the neighbourhood of Christiansund and Molde, following valleys to the heads of the fjords into which they trend. The country, which is mountainous and traversed by deep valleys, is formed of metamorphic crystalline schists with eruptive rocks. The Sell-Storen line coincides roughly with the junction of two great series of the schists, the older constituting generally the ground to the west and the younger that to the east. It is in the latter set of rocks that the ores of the region are found at a great many spots noted and more or less described in this paper. These ores—iron- and copper-pyrites—occur chiefly in bed-like masses approximately parallel to the high dip of the foliated rocks amongst which they lie, and several of them have been worked already. Thus the pyrites-mine of Undal, about 20 miles south of Storen, has been exploited since the seventeenth century, and is capable of producing 20,000 tons of pyrites (1 per cent. of copper) per annum, at a price of 8s. 9d. (7·75 kroner) per ton at Trondhjem. The Foldal mines can produce double that amount (with 2 per cent. of copper) at about 10s. 1d. (9 kroner). These localities, with Varstian, are the most important; but several others—some with chromium-ores—are cited. Alternative railways for the development of the pyritous deposits of the district are suggested and discussed, and are illustrated by means of rough sections and a sketch-map. G. A. L.

MINERAL RESOURCES OF RUMANIA.

Etudes sur les Minéraux de la Roumanie. *By* PROF. P. PONI. *Annales Scientifiques de l'Université de Jassy*, 1900, *vol. i., pages* 15-148.

This memoir is an exhaustive compendium of all that is known up to the present day concerning the minerals of Rumania. In regard to those of industrial importance, the following are the chief particulars which may be gleaned from the memoir:—

Petroleum occurs on the northern slope of the Moldavian Carpathians and on the southern slope of the Wallachian Carpathians. Its origin is in some way connected with the upheavals which resulted in the ridging up and folding of the Carpathian range. The chief centre of the oil-industry is the district of Prahova, producing more than 23,000,000 gallons annually. Next in importance are the districts of Buzeu, Dimbovitza (where the production, however, is diminishing), Neamtz-Bacau, etc. In 1898, the total amount of petroleum produced in Rumania exceeded 30,000,000 gallons; the use of the crude oil and of the distillation-residues as fuel in factories and railway-locomotives is rapidly extending in that country, and the author thinks that the production in 1899 was vastly greater than that of the previous year. Moreover fresh facilities for transport of the oil along the navigable waterways have lately come into play.

Ozokerite has been worked in several localities, where beds of it occur in association with petroleum.

Amber is got chiefly in the district of Buzeu. The mountain-torrents coming down in flood bring with them great masses of friable Miocene sandstone and clay in which the mineral occurs, and whence it is extracted by the people of the countryside. The annual production varies: it is stated not to exceed 660 pounds, but there is reason to believe that the peasants conceal the actual amount, in order to evade taxation.

Anthracite containing between 88 and 90 per cent. of fixed carbon is worked

at Schela in the Gorjiu district, and is known to occur at three or four other localities.

Bituminous coal, of Jurassic age, occurs in the Dimbovitsa district. There, at Brandusi, are two seams—one 6½ feet, the other 2½ feet thick. At Piscul-cu-brasi two seams have been struck, the lower of which, 2¾ feet thick, is separated from the upper (27 inches) by only 1 foot of clay.

Lignite is of widespread occurrence. The workings at Bahna and Meris have been abandoned, but in the Dimbovitsa district a seam, ranging from 6 to 7 feet in thickness, is worked, and 8,500 tons were got from it in 1898. Exploration-work is going on at Doicesci in the same district, where three seams crop out whose combined thickness approaches 20 feet. This is also the maximum thickness of the three seams in the Government mine at Margineanca; at Fagetzel, 4½ miles distant from the last-named locality, opencast lignite-workings were started by the Rumanian Government in 1898. The mineral is also being mined at several localities in the Prahova district.

Graphite has been recorded from the Suceva, Gorjiu and Mehedintsi districts, but it does not appear that any attempt has been made to work it.

Rock-salt is, industrially, one of the most valuable of the Rumanian minerals owing to the extent, thickness, and purity of the deposits. These form an almost unbroken chain, striking firstly north and south on the eastern flank of the Moldavian Carpathians, and then striking westward on the southern slope of the Wallachian Carpathians. As a general rule, the rock-salt crops out at the surface, or is struck at a very shallow depth. The working of the mineral practically constitutes a state monopoly, the chief mines being those of Tirgul-Ocna, Slanic, Doftana, and Ocnele-Mari. Galleries, 160 feet or so wide and 650 feet long, are driven in the rock; and though, in some cases, the workings have reached a vertical depth of 600 feet or more from the surface, they have not got through the salt. The total production of the four above-mentioned mines in 1898 exceeded 112,000 tons, 64 per cent. of which was consumed within the country, the remainder being exported to Bulgaria, Servia and Russia.

Gypsum, as might be surmised, is of very frequent occurrence in association with the salt-deposits.

Mirabilite (Glauber's salt, or hydrated sodium sulphate) occurs abundantly in deposits crystallized out from the many salt-lakes of the Rimnicul-Sarat, Braila and Jalomitza districts. As the outcome of elaborate analysis and comparisons the author concludes that the waters of these lakes could be utilized in the industrial preparation of sodium sulphate with much greater advantage than the "mother-liquors" of salt-marshes. Sodium sulphate also occurs in the efflorescent form at the surface of porous marls (proved to overlie saliferous clays) which are found mostly in the valley-bottoms of the Bahlui and Jijia river-basins and at many other localities. Finally it occurs in solution in the springs and wells around Jassy, etc., and among the Carpathians, in springs, in close proximity to the great chain of rock-salt deposits.

Kaolin.—The granulite of the south-western flank of Mount Muncel is believed to have given rise to a thick deposit of kaolin, which occurs in a neighbouring valley.

Iron-ores occur in workable deposits in several localities, such as the magnetites between Podeni and Obirsa; the limonites on the western flank of the Bahna mountains, and of Mount Dirmoxa; and perhaps the red hæmatites of the Suceva district. Moreover, iron- and copper-pyrites, and manganese-ores are recorded from several localities.

Gold occurs, but in very small proportions, in the river-sands of the Jiul, the Oltul, the Argesul, the Bistritza and their mountain-affluents.

Among the other minerals, the existence of which is proved, are native sulphur, native mercury, cinnabar, realgar, orpiment, galena, blende, smaltine, tetrahedrite, malachite, etc. L. L. B.

MINERAL PRODUCTS OF CEYLON.

Ueber die Mineralvorkommen von Ceylon. *By* FR. GRÜNLING. *Zeitschrift für Krystallographie und Mineralogie*, 1900, *vol. xxxiii., pages* 209-239, *with a figure in the text and map.*

This memoir is based partly on the author's personal observations in the course of a journey through Ceylon in the winter of 1896-1897 (made for the express purpose of collecting minerals), and partly on an exhaustive study of all known publications bearing in any way on the mineral products of the island.

From the physiographical point of view, Ceylon is divisible into three very distinct portions: (1) the northern plains; (2) the low coast-lands; and (3) the mineral-producing mountain area, which, lying somewhat south of the true centre of the island, takes up about a fifth of its total surface.

In northern Ceylon, especially in the districts of Chilaw and Puttalam, sea-salt is got by solar evaporation of the sea-water in narrow canals: the numerous shallow inlets and creeks are very favourable to this branch of industry. Along the north-western coast, from Negombo to the island of Mannar stretch the pearl-oyster banks. The pearl-fishery is subjected to careful regulation and inspection, and operations (when authorized) are usually started about the end of February, at the quietest period of the north-east monsoon. In 1885, for example, pearl-fishing was carried on for 20 days, the total value of the production for that short campaign amounting to £9,000.

Turning now to the mountainous districts, the mineral which ranks first in industrial importance is graphite. It is of widespread occurrence, and is worked in numerous mines, pits and smaller excavatons over an area extending from Mount Ambokka, on the boundry between the Central and North-western Provinces, to Warapitiya in the Hambantota district of the Southern Province, and from Matalé up to the heights of Nuwara Eliya. The estimates of the total number of workings appear to be very various, ranging from 400 up to 1,800 or thereabouts. The workings are generally opencast, and are exploited in a comparatively primitive fashion, very few steam-engines being in use. One of the great practical difficulties is the inrush of water, particularly after heavy monsoon rains which at times bring mining operations to a standstill. In some cases, perpendicular shafts are driven in the graphite-bearing rocks, but to no very great depth, on account of the bad conditions of ventilation. The largest mines are those of Ragedara, which have yielded and still yield enormous quantities of graphite of first-rate quality. Next perhaps to these we should mention those of the Kegalla district, and of Pasdum Koralé and Morawak Koralé. Messrs. Walther, Zirkel and Weinschenk have successively pointed out that the graphite is a true vein-deposit (in granulite), a view with which the author emphatically concurs.* The graphite-veins have preserved in a remarkable

* *Quarterly Journal of the Geological Society*, 1900, vol. lvi., page 609.

way the impress of the mechanical disturbances (the dynamics of mountain-building) which the rocks have undergone since the veins were formed. Thrusts in opposite directions have produced in the graphite-fibres a structure of deceptively ligneous aspect, while in some cases excessive pressure has converted the fibrous graphite into a compact, minutely scaly mass. This variety is regarded in Ceylon as of less value, nevertheless it possesses all the qualities requisite for making good pencils. For further information on the subject of the graphite-deposits of Ceylon, the reader may consult with advantage Dr. E. Weinschenk's paper.*

Precious stones occur in the recent river-sands and in the older alluvial deposits, now high and dry above the stream-levels. Among the wealthiest areas in this respect is the province of Sabaragamuwa (wherein the town of Ratnapura is regarded as the chief centre of the industry) down to Rakwana; and away over the southern hills to the sea, thence along the coast-lands from Point de Galle to Magama Ganga (Southern Province). Rich deposits too are found in the Western Province. The methods of working are of the simplest, and are carried on almost exclusively by Cingalese natives. The "water-pits" are worked only at certain seasons, for the streams are mightily swollen during the monsoon. At a convenient spot, the river-bottom is scooped up with long-handed shovels bent at right angles: then 30 to 40 shovelfuls, say, are emptied into a basket of closely matted plant-fibre with small oblique apertures. The basket is kept see-sawing in the water with a kind of rotatory motion, the result being that clay, mud, dirt, etc. are washed out while the clean gravel remains. In the case of "land-pits," a fairly deep tank is dug, wherein a wooden stand is built for the man who washes the gravel: otherwise the *modus operandi* is practically the same as that just described. The precious stones are mostly fresh and bright, and but little rolled, showing that they cannot have travelled far from their original home. Some of the stones are sold by auction or private treaty just as they are, but others are cut in Ceylon itself, and the author publishes a photograph and description of a native cutter at his work.

Among these stones, the great abundance of corundum is very striking, so too its varied coloration and degree of translucency. The most frequent precious corundum is sapphire of a pale blue (the natives "improve" the colour to a certain extent by heating the stone). Colourless and fine yellow sapphires are fairly common also, but of less market value. Rubies are much rarer: they vary in colour from a pale raspberry pink to one with a violet tinge. In this case also defects of coloration are partly got rid of by heating. Gneissose and granitic rocks are said to be the original matrix of the sapphires, while the rubies are traced back to dolomites and limestones as well. The author, however, has collected material affording evidence that dolomite is also the mother-rock of sapphires.

Magnificent blue spinels, zircons and tourmalines are of frequent occurrence. Colourless zircons are mostly cut in rosettes, and are termed "Matará diamonds."

Shimmering moonstone is found in pegmatite-veins, especially in the district of Kandy, while gravels derived from such veins occur in the Galle and Matará districts of the Southern Province. Ordinary garnet and brown cinnamonstone are also cited, as well as amethyst and colourless rock-crystal.

Among the minerals which the author did not himself find, but the occurrence of which is recorded on reliable evidence, are sulphur, platinum, native gold, auriferous quartz, molybdenite, magnetic pyrites, magnetite and iron-alum. L. L. B.

* *Zeitschrift für Praktische Geologie*, 1900, vo viii., page 174.

DEVONIAN ANTHRACITE IN KWI-CHU PROVINCE, CHINA.

Sur la Présence d'un Gisement d'Anthracite Dévonien au Koui-tcheou, Chine. By G. H. MONOD. *Comptes-rendus Hebdomadaires des Séances de l'Académie des Sciences*, 1901, *vol. cxxxii., pages* 270-272, *with a plan and section in the text.*

By means of three very narrow drifts, the most considerable of which, at the time of the author's visit, was about 5,000 feet long, the Chinese work a deposit of anthracite at Lan-mu-chang, halfway between the cities of Hing-i and Gan-shuen, in the province of Kwi-chu. The coal is overlain and underlain by highly fossiliferous pyritous grey shales; and above the shales are limestones. In the last-named formation is a small fissure encrusted with cinnabar, which has also been worked by the Chinese. The presence of sulphides accounts possibly for the somewhat high proportion of ash in the anthracite; a proximate analysis made at Marseilles yielded the following percentage results:—Moisture, 0·50; volatile matter, 8·75; ash, 10·40; and fixed carbon, 80·35.

The coal-seams, of which there appear to be three, dip 20 degrees north-eastward, and the fossils found in immediate association with them prove their Devonian age. This shows that the coal-bearing formations in China range through a much greater period in geological time than had been previously suspected. This range is still further extended, when we take into account the occurrence of Tertiary lignites recorded by the author at Ma-pe-kai in the east of Yun-nan: with these lignites is associated an abundant fauna of lacustrine gasteropods. Moreover, Mr. Zeiller has shown that lignites, probably of Pliocene age, are to be found in Tong-king, in the neighbourhood of Yen Bay. L. L. B.

AURIFEROUS DEPOSITS OF THE LIAO-TUNG PENINSULA, CHINA.

Geologicheskoye Opisanie iuzhnoi okonechnosti Liao-Dunskago Poluostrova ve predielakh Kvantunskoi Oblasti i eia Miestorozhdeniya Zolota. By K. I. BOGDANOVICH. *Materiali dlia Geologiyi Rossiyi*, 1900, *vol. xx., pages* 1-248, *with two maps, plates I.-XV., and a summary in French.*

This elaborate memoir, forming by far the greater portion of the twentieth volume of the *Materials for the Geology of Russia*, deals with the geology of the Kwantung province or southern end of the Liao-Tung Peninsula, ceded to the Tsar by the treaty of March 15th, 1898.

The author has determined the rock-succession in Kwantung as follows (each group being markedly unconformable one to the other):—(1) Gneisses, granitoid gneisses, and hornblende-schists (? Archæan metamorphic series); (2) quartzites, quartzose grits and clay-slates of Ta-ku-shan; (3) limestones and shales of Cambrian age; and (4) Coal-measures (grits, shales and limestones) of Carboniferous age.

The foregoing rock-groups are enumerated in ascending order; the topmost or Carboniferous group is at present only known by two small outcrops.

Above all these come the sub-recent alluvial deposits, loess-clays and loams, raised beaches, etc. Eruptive rocks play a very insignificant part in the configuration of the area. The orographic structure shows signs of considerable earth-movement as early as pre-Cambrian times, and dislocatory movements continued until after the deposition of the Carboniferous strata, since these too have been folded and ridged up.

The author distinguishes in the Liao-tie-shan district four categories of auriferous placers: (*a*) recent gold-bearing sand in the river-beds; (*b*) placers of the table-lands and hills, formed from the erosion of rocks *in situ* or on neighbouring slopes; (*c*) gold-bearing alluvia of the valleys, dating from the period of formation of the river-valleys; and (*d*) submarine gold-deposits, the last-named being worked by the Chinese at low tide.

The exploration of the placers in the Pei-lien-tsa valley and near the village of Shantse-tun has yielded evidence of their connexion with quartz-veins which traverse the quartz-schists and clay-slates of the Ta-ku-shan group. In the Liao-tie-shan massif these veins are seen to traverse also the Archæan gneisses and granitoid rocks, and they seem to bear some relation to an associated complex of pegmatitic veins.

Around Port Arthur, gold-placers belonging to categories *a* and *b* have been discovered, and so too farther north-east near the bay of Liao-pin-tao. Several other localities for gold are enumerated, and the memoir conveys generally the impression that both placers and auriferous quartz-veins are very widely spread over this new province of the Russian Empire. Exploration-work is now in progress, with the view of ascertaining whether the veins, which are never more than 1½ inches thick, could be worked at a profit, but there is no doubt whatever as to the industrial importance of the deposits belonging to categories *b*, *c* and *d*. The last-named—the submarine placers—are regarded by the author as the most promising of all. The Chinese Government had always opposed the working of gold in this area, but in 1898 the people of southern Liao-tung, being pressed by famine and taking advantage of the relaxation of Chinese authority, began to excavate the placers: and a change has come over the economic as well as over the political conditions of the peninsula. L. L. B.

MINERAL RESOURCES OF TAIWAN OR FORMOSA.

Unsere geographischen Kenntnisse von der Insel Taiwan (Formosa). By Dr N. Yamasaki. *Petermanns Mittheilungen*, 1900, *vol. xlvi., pages* 221-234, *and map.*

The most important mineral products of the island, now happily under Japanese rule, are gold, coal and sulphur, and the chief localities so far known for these are in the extreme north, in the neighbourhood of Kilung.

The gold occurs both in placer-deposits and in veins: it was first discovered in 1890 in the Kilung-kei river by one of the Chinamen employed in building a railway bridge. Since then, a stretch of 10 miles of river-bed has been industriously washed for gold by thousands of natives. Later on, auriferous sands were found at Shinjō and in the Shū-koran-kei on the east coast. In the Kinkaseki and Kyūfun-san hills, east of the harbour of Kilung. gold occurs at the contact-zone between Tertiary sandstones and slates and volcanic rocks, and in veins interrupted by Tertiary beds.

Many coal-seams occur in the Tertiary hill-country on both sides of the Kilung-kei, but on the whole the quality is not very good. Among the localities where the coal is said to be somewhat better are:—Shikyakutei (three seams, of which the main seam is more than 4 feet thick); Denryōkō (also three seams, the principal of which attains a thickness of 9 feet 8 inches: but they all thin out gradually westward); and Sanshōrei. The use of the Kakyaku coal-field is exclusively reserved for the Imperial Japanese Navy: it opens up four seams, of which the main seam is 5½ feet thick. All the coal-

bearing strata are Tertiary sandstones and shales, with a general north-easterly and south-westerly strike, and sometimes a steep dip (as much as 85 degrees). The coal-export in 1898 amounted to 14,250 tons.

Sulphur is got from the solfataras connected with the Taiton volcanoes, and the annual production ranges between 300 and 420 tons.

Petroleum is known to occur in several localities, but so far it has not been obtained in sufficient quantity to make it of great industrial importance.

The author embodies these data in a paper which contains much valuable information concerning the physiography, climate, vegetation (rice, tea, pine-apples, bamboo, sugar-cane, camphor, etc., are grown), and fauna of the island. L. L. B.

PROSPECTING IN PERSIA.

Schürfungen in Persien. *By* HANS WINKLEHNER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 629-633 *and* 645-649.

Petroleum.—Near Schushter is a hot spring yielding 22 to 33 gallons (100 to 150 litres) *per diem* of petroleum, fit for burning without requiring any refining. Another source of oil is found in a hot sulphur-spring at the foot of a limestone-hill near Daliki, the daily output being 18 to 22 gallons (80 to 100 litres) of clear yellow oil, with a specific gravity of 0·81, agreeable odour, and burning well without smoke. Two abandoned bore-holes sunk in the vicinity were examined by the author, but the quantity of oil was small; and, though the presence of workable quantities is not improbable, the expense of transporting tools, etc., from the coast is so great that there is little likelihood of the deposit being worked.

Other petroliferous springs were discovered in the limestone-formation near Chanäwallah, but the same objection applies to any endeavour to work them; and oil was also found on the island of Kishim in the Persian Gulf. Notwithstanding the failure of previous attempts the author is of opinion, in view of the great extent of country of uniform geological character along the shores of the gulf, from Schushter to Minab, over which these oil-springs occur, that payable oil may yet be struck at some parts of the line.

Rock-salt.—Very extensive deposits are found over the whole of Persia. A large part of the chain of hills along the Persian Gulf, some 93 miles (150 kilometres) between Bushire and the Rud-i-Mand, consists of saliferous clays containing from 20 to 30 per cent. of salt. The outcrop in many places takes the form of pillars or pyramids 160 to 200 feet (50 to 60 metres) high, covered with overhanging sandstone protecting it against further denudation. The hill of Kuh-i-Namak, near the mouth of the Rud-i-Mand, and about 5,200 feet (1,600 metres) high, consists mainly of rock-salt overlying marl and tough limestone. A similar deposit occurs at Namakdan on the island of Kishim, a chain of hills 3¾ miles (6 kilometres) long, 3,900 feet (1,200 metres) wide and over 300 feet (100 metres) high, on the southern coast, consisting entirely of rock-salt, with a covering of sandstone, marl and gypsum. The salt here is very clear and transparent. It is worked in a very primitive manner by the natives, home-made powder being employed for blasting.

Other considerable beds, but of less pure salt, are found in the islands of Hormuz, Larak and Handscham.

The chief difficulties in working these beds on a large scale are the provision of food and water for a large working staff, the land being unproductive and

short of water. The main drawback, however, is the high freight to Bombay, there being no return traffic; and consequently this district could not compete with the Aden salt-works.

Coal.—Several outcrops of so-called coal were inspected in the Gisakhun, Dehery and Chormudah hills, but proved to be gypsum, etc., impregnated with bitumen, the only deposit of true coal being in the hills to the north of Kerman. Even this is very irregular, and occurs in isolated masses 31 to 47 inches (80 to 120 centimetres) thick; and, though of good quality, is too far from the coast to be of any practical value.

Borax.—Between Shär-i-Babek and Deh-i-Shuturan, in the province of Kerman, an extensive deposit of borax occurs in the centre of a steppe, the mineral being found in lumps about 40 to 60 inches below the surface. The soil is impregnated with boracic compounds, and the subsoil water is struck at a depth of about 80 inches (2 metres). The lumps consist of: ulexite, 68·93; boracite, 1·00; borax, 2·06; glauberite, 4·76; common salt, 4·22; moisture, 11·26; and insoluble matter, 7·85.

The natives extract the borax by boiling these lumps for 4 to 5 hours in a solution of plant-ashes and crystallising the extract in copper pans.

The author collected a quantity of the lumps, and concentrated the borax by washing out the earthy impurities and drying the ulexite in kilns, the product containing 55 per cent. of boric acid, 16 per cent. of lime, 8·8 per cent. of soda, and 20·2 per cent. of moisture.

Asbestos.—The best finds were made in the Kuh-i-Benan hills on the Afghan frontier, and at Bafk, Chusf and Shetur in the same district, the mineral being associated with serpentine in limestone.

Iron.—A considerable deposit of red ironstone, 30 to 60 feet (10 to 20 metres) thick and of a soft character was found near Bam, the outcrop being traced for nearly 2,600 feet (800 metres). The ore is of excellent quality, containing an average of 56 per cent. of iron, and is embedded in limestone; but owing to its position in the desert, 37 miles (60 kilometres) from the nearest water, is practically unworkable.

Copper and lead are fairly plentiful in the south, the former being worked in the Kuh-i-Hasar hills (Kerman), and the latter at Kuh-Kebutih (Bam), where a very rich deposit occurs in a limestone-ridge.

Sulphur.—Irregular deposits of impure (20 to 25 per cent.) sulphur are found in some low hills near the headland of Ras Bostana and worked by the natives. Pockets of purer mineral (70 to 80 per cent.) are also met with in the same locality.

Unfortunately the almost entire absence of any means of internal communication, apart from a few main roads, precludes the possibility of utilising the mineral wealth of the country. C. S.

MINERAL WEALTH OF SIBERIA.

Note sur les Richesses Minérales de la Sibérie et sur l'État actuel de leur Exploitation. By E. GLASSER. *Annales des Mines*, 1900, *series* 9, *vol. xviii., pages* 5-78, *with maps in the text and a map.*

This exhaustive memoir is based partly on the author's personal observations made during the summer of 1898, and partly on information elicited from Russian mining engineers and mining publications. It is accompanied by a sketch-map of Siberia on which the most important ore-deposits so far known are indicated. The author expressly excludes from the scope of his survey the mineral wealth of the Ural region and of Russian Central Asia.

Gold.—The seekers after the precious metal, pushing ever farther afield as the gold-bearing deposits nearer the fringe of the settled districts are becoming gradually worked out, have recently entered upon regions hitherto regarded as practically uninhabitable—the desolate shores of the Sea of Okhotsk, nay even far Kamshatka itself. A certain measure of success has already attended their efforts, thus confirming the supposition that auriferous deposits extend in an unbroken chain from the Urals to the Pacific coast. The gold-production of Siberia in 1897 reached 897,210 ounces troy, the number of workpeople employed being close upon 45,000. The largest amount of gold is got from the Lena district and the Amur province, which between them account for more than half the total. Then *longo intervallo* come the Yenisei district, the Maritime province, the Altái, and Eastern and Western Transbaikalia. It is believed that a considerable proportion of gold is stolen by the workpeople; and further, that a good deal is worked clandestinely in order to evade taxation: the result being that the declared production represents probably not more than three-quarters of the real total. The undeclared fourth is smuggled across the Chinese frontier, or stealthily conveyed on board vessels lying in the Pacific harbours.

As before mentioned, the Lena district is at present the most important gold-producing area in Siberia. The rigorous climate does not allow of the hundred or so placers being worked during the winter, although some underground exploration and driving of headings, etc. is done then. The land, not having been brought under tillage, yields no food; and, besides the workpeople themselves, provisions, stores, everything in short, except timber, have to be brought thither from enormous distances. Wages are comparatively high—including the market value of the food supplied, they average 6s. to 6s. 8d. *per diem*. In the working season of 100 days one workman's output will amount to 25·72 ounces troy of gold. Taking as an example the Olekma and Vitim portion of the district, highly folded schists and sandstones of Cambrian and Lower Silurian age are capped locally by Pliocene and Quaternary deposits. The ancient rocks are rich in auriferous pyrites, containing as much as 5 to 7·5 parts of gold per 10,000, and they are believed to be the source from which the placers derived their materials. The percolation of surface-waters during the emergence of the area, in the long ages which elapsed between the close of Palæozoic and the end of Tertiary times, probably gave rise to auriferous quartz-veins in the fissures of the rocks. These veins were weathered away during the Glacial period, and their constituents accumulated into the older and richer series of placers, with a general north-easterly and south-westerly trend. These placers lie deeply buried beneath a double succession of Glacial deposits, which are in turn overlain by the auriferous alluvia of the modern rivers. Fluviatile erosion of the older placers has given rise to the distribution along the present valleys of post-Glacial placers, shallower and poorer in gold, but less deeply buried beneath barren deposits (in this case only gravel and peat). The older placers are exploited by underground workings, the newer by opencast. The necessity of thawing the deeply frozen subsoil and the auriferous sands themselves is one of the many difficulties with which the Siberian miner has to contend, and the underground galleries must perforce be very elaborately and carefully timbered.

In the Amur province, the chief centre of gold-mining industry is the Zeia river-basin. Although it lies several degrees south of the Lena district, the climate is still too rigorous to allow of a longer working season than 110 to 120 days. The lower course of the Zeia is navigable all the way down to

its confluence with the Amur, near which point is the important town of Blagoveshchensk. The Zeia placers are spread over a belt about 60 miles broad and 370 miles long, trending east and west parallel with the plications of the Stanovói Range: they occur generally near the contact of gneisses and mica-schists with granitic masses. The placers are evidently of sub-recent origin, shallow, and not deeply buried under barren deposits, so that the workings are all opencast. The material which constitutes the auriferous deposits does not appear to have travelled far. As is the case all over Siberia, the sluice-boxes are made very short, and contain no mercury, with the result that much finely divided gold is lost. Improved methods and appliances would make it pay to work deposits now considered exhausted or regarded as too poor. An unsuccessful attempt at dredging was made some years ago.

In the Yenisei district, besides placers (the total production of which has diminished year by year since 1857) auriferous quartz-veins in the ancient rocks are now being worked. After a brief description of the conditions obtaining in the other areas previously enumerated, the author concludes that, on the whole, the gold-reserves of Siberia are still considerable, and that for many years to come production will maintain its present level, with perhaps a few fluctuations.

Silver and Lead.—At present only five argentiferous deposits are being worked in all Siberia: two in the Altái, one in Transbaikalia, and two in the Kirghiz steppes. The abolition of serfdom in 1861, causing a sudden rise in wages, struck a deadly blow at the prosperity of the Altái mines, and the *coup de grâce* was given by the fall in the value of silver. A similar statement applies to the Transbaikalian mines, which, for more than a century, were worked by convicts. Now convicts are sent on to Sakhalien Island, where their labour is largely hired by colliery companies. There is reason to believe that in both the Altái and Transbaikalia only the very richest veins have been worked out, and that payable argentiferous deposits remain untouched until such time as improved means of communication and other favourable circumstances combine to attract attention to them once more.

Copper.—The same obstacles arrest the progress of this industry as those which have been hinted at in the case of silver and lead. In the Kirghiz steppes, cuprite, azurite, malachite, and a whole series of sulphides occur at the contact between the porphyrites and the Devonian grits and limestones.

Cinnabar and *tin* are recorded from Transbaikalia, and *zinc*-ores have been discovered in many parts of Siberia.

Iron.—Although a great many occurrences of magnetite, spathic ore, and hæmatite are recorded in Siberia, not more than six or seven different deposits are worked there, and those not very actively: the total production of iron-ore in 1897 only amounted to about 20,000 metric tons. Five foundries are at work (all in Central Siberia) two of which belong to the Administration of the Privy Purse, while three are the outcome of private enterprise. The Nikolaievsk works are the most important: they have been in private hands since 1864, and the plant has been largely remodelled of late years; they employ 960 workpeople. The ore used there is a splendid brown hæmatite from the Devonian sedimentaries of the Angara valley: the fuel is wood and wood-charcoal.

Coal.—The total production in Siberia, during 1897, amounted to 55,480 metric tons, four-fifths of which came from the Pacific coast, and nearly the whole of the remaining fifth from the Kuznetsk basin. The last-named is at present the most important coal-field in Asiatic Russia: it is formed by an outlier of true Coal-measures amid the Devonian rocks which cover a vast

extent of country, north of the Altái massif. The coal-field extends 125 miles from north and south between the Alatáu Hills on the east and the Zaláirsk Hills on the west, and is 30 miles or so broad. On the banks of the Tom (an affluent of the Obi), which runs right through the coal-field from north to south, rises the town of Kuznetsk. The Coal-measures are about 1,300 feet thick, and consist of an alternation of very clayey grey shales with more or less compact sandstones. In these occur a great many seams, at least a dozen of which are more than 39 inches thick, and one seam at certain points actually reaches a thickness of 40 feet. All the seams together average a total thickness of more than 95 feet of coal. The quality is good, but the mineral has so far been worked actively at one point only—that is, at Kalchughón, on the western lip of the basin, where the seams are very thick. This locality is hardly more than 30 miles distant from the Privy Purse ironworks of Gurievski, where the coal has been largely used, as such, and in the form of coke as well. At present the only available means of communication are rough corduroy tracks through the marshy forest.

About 60 miles north of the Kuznetsk basin, another coal-field, near Sujenka, but in immediate proximity to the Trans-Siberian Railway, was opened up by exploration-work in 1897 and 1898, and was expected to produce in 1899 about 50,000 metric tons at an estimated cost of 8 shillings per metric ton. South-west of the Kuznetsk basin, patches of Coal-measures occur in the Kirghiz steppes, and exploration work is in active progress. So it was also in 1898, near Nakhotka bay, about 30 miles east of Vladivostok, while the Nadiezhda coal-field, about 12 miles north of Vladivostok was estimated to yield in 1899 about 20,000 metric tons suitable for use on the railway. Further, the collieries on the coast of Sakhalien are being rapidly developed, and there are vast unworked deposits in the interior of the island: the price of coal on that coast does not exceed 15 shillings per metric ton.

Anthracite, graphite, and *naphtha* also occur in Siberia. L. L. B.

THE ORIGIN OF GOLD IN MADAGASCAR.

Sur l'Origine de l'Or de Madagascar. By A. Lacroix. *Comptes-rendus Hebdomadaires des Séances de l'Académie des Sciences,* 1901, *vol. cxxxii., pages* 180-182.

Native gold occurs in the alluvial deposits over the whole area of gneissic rocks in Madagascar, but exploration-work has so far been concentrated on the central massif of the island. Quartz-veins, the usual primary matrix of alluvial gold, have not been much studied up to the present in the new French colony, and little is known definitely about them there, excepting three veins which were actually worked in the neighbourhood of Suberbieville before the annexation. The author's opinion is that much of the Madagascar alluvial gold is really derived from a gneiss of which it was a normal constituent. The only other known occurrence of native gold as a primary constituent of gneiss is in the Campanha district of Minas Geraes (Brazil). But several examples are known of the occurrence of gold in granitic magmas, and therefore the author is not surprised to find it in such crystalline schists as those of Madagascar, where the influence of eruptive granite is traced at every step. Moreover, the auriferous quartz-veins of the island are manifestly connected in some way with the granite, for parts of them are masses of rock-crystal with inclusions of tourmaline and muscovite.

Gold has been found, and should be further sought, in the laterite (or red earth), which, in Madagascar, as in many other tropical countries, is the result of the decomposition *in situ* of felspathic rocks of every description (gneiss, granite, etc.). The biggest nuggets as yet obtained in the island were got from this laterite; they are quite "unrolled," and are doubtless there in their original matrix.

Moreover, in the magnetiferous quartzites, the principal source of iron-ore in Madagascar, native gold occurs in just the same way as the magnetite—that is, it encrusts the quartz-grains or is completely enveloped by them. It is intimately associated with the magnetite, and is doubtless one of the primary constituents of the rock. L. L. B.

GALENA ASSOCIATED WITH VANADIUM AND MOLYBDENUM-ORES IN ARGENTINA.

Bleiglanz-, Vanadin- und Molybdänerzgang in der Provinz San Luis, Argentinien, Südamerika. By DR. W. BODENBENDER. *Zeitschrift für Praktische Geologie*, 1901, *vol. ix., pages* 52-55.

The quartz-vein which exhibits this uncommon mineral association was discovered not long ago in the province of San Luis. At the outcrop it is about 6½ feet thick, strikes northwestward with a vertical pitch, and cuts through phyllite. The vein is divisible into six different bands on either side of its central axis. Beginning with the outermost, we find:—

1.—Compact or porous quartz with limonite, hæmatite, and a minute proportion of gold.

2.—A compact or cavernous, granular or homogeneous, red or brown mass, consisting of silica, iron-oxide, and carbonates of lime and lead. In this are nests and druses of plumbo-calcite, which, on analysis, is shown to contain phosphates and molybdenates; the hollows in this gangue are in part occupied by chrysocolla, cerussite, quartz, vanadinite, molybdeno-silicate of copper, etc.

3.—A compact, homogeneous, black-grey layer consisting chiefly of carbonate of lead, with calcite, small quantities of galena, copper-pyrites, iron-ore, and very little quartz.

4.—An extremely thin band (only about 0·20 inch) of sulphate of lead of a greyish-white colour. Sometimes this pinches out altogether.

5.—A compact, homogeneous, black or dark blue layer, consisting of sulphides of lead and copper mingled with plumbic sulphate. This gradually passes into

6.—Where small crystals of galena dispersed in a greyish-white mass of lead sulphate pass little by little into the coarse-grained galena which forms the core of the vein.

Very near the spot to which the foregoing description applies, and working on the same vein, large masses of plumbo-calcite were got, mostly free from quartz and limonite, but encrusted with red iron-ochre. In this plumbo-calcite were *tabulæ* and nests of a lemon-yellow and orange-yellow mineral which proved to be, if not actually wulfenite (a molybdenum mineral), at least closely akin to it; and this was associated with tiny crystals of a vanadium-lead mineral. The author regards the vanadinates as the latest-formed secondary products in this vein; the whole ore-body being the outcome of successive deposition of metallic and non-metallic compounds from aqueous solutions percolating into a fissure. The ferruginous and auriferous quartz

was the first mineral to be deposited; it is possible, indeed, that it filled up the whole of the original fissure, but that this was reopened later after partial shattering and smashing up of the quartz.

The order of deposition may be inferred from the enumeration (abstracted above) of the various layers which go to form the vein. The genesis of the vein seems to be connected in some way with that of the pegmatites.

After pointing out that bismuth-ores in the same province of San Luis, previously reported as occurring in gneiss, really occur as veins in pegmatite, the author remarks that vanadium minerals are widely distributed in the mountains of that province and Córdoba, but nowhere do they occur in large masses. They seem to disappear in depth, while galena usurps the pre-eminence. The prospect is not encouraging for mining enterprise exclusively directed to the vanadium minerals, and workings begun but a short while since have been abandoned. L. L. B.

IRON-ORE DEPOSITS OF VANCOUVER AND TEXADA ISLANDS.

Iron-ore Deposits of Vancouver and Texada Islands. *By* Wm. M. Brewer. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxix., page* 526.

The possibilities of extensive iron- and steel-works on either Vancouver or Texada Island have never been thoroughly discussed. Californian capitalists, being impressed several years since with the importance of the iron-ore deposits on Texada Island, secured a large tract of land by Crown grant from the Provincial Government. The same syndicate erected a charcoal blast-furnace at Irondale, Washington, and for a time manufactured pig-iron of very superior quality. For some commercial reason the furnace was blown out, but a small gang of men was kept on prospecting-work. At a level of 277 feet below the workings from which the ore was originally extracted, it has been determined that a good grade of iron-ore occurs, the body being about 70 feet thick. This is the deepest work so far done on any part of the iron-ore deposits on either island. The ore is magnetite with phosphorus below the bessemer limit, and it occurs at the contact of crystalline limestone and diorite. Along the line of strike, the outcrop can be traced for about 1½ miles; it forms prominent bluffs in many places, and there is every indication that the deposit is of vast magnitude.

On the west coast of Vancouver Island, iron-ore very similar to that found on Texada Island occurs near Sechart Landing, as well as on Copper Island. It is estimated that there are 6,000,000 tons of iron-ore in sight on Copper Island. At the Sechart deposits, prospecting has been carried on for the past few years, and the owners estimate a vast quantity of ore in sight. For the manufacture of iron, copper-contents in the ore depreciate its value, but the results of deep working on the iron-ore deposits on Texada Island, should encourage further exploration, for the copper-values, instead of increasing, have disappeared entirely.

On the west coast of the mainland of British Columbia, 80 miles north of Vancouver Island, another ore-deposit of magnetite occurs between granite and limestone. This ledge of iron-ore is 30 feet wide, and the limestone on the foot-wall side about 40 feet wide. The average of several analyses gave about 70 per cent. of metallic iron and 0·01 per cent. phosphorus.

Crystalline limestone of apparently the same grade as that so successfully used at present for flux occurs in close proximity to all the iron-ore deposits, and a good grade of coke is available on the east coast of Vancouver Island.

There are also in the vicinity of Port McNeill coal-fields which have never yet been opened, and on the north-west coast of the Island. There are extensive fields of anthracite on Queen Charlotte Island: they have not yet been opened, but experts report that the seams are of great thickness, one measuring 18 feet. X. Y. Z.

GOLD-FIELDS OF WESTERN ONTARIO.

The Gold-fields of Western Ontario. By J. D. Lowry. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxx., page* 246.

The gold-fields of Western Ontario extend from the Province of Manitoba on the west to Lake Superior on the east, and from the international boundary-line on the south to a line 130 miles north, covering an area of 30,000 square miles. The whole region is still practically a virgin field. The ore is nearly all free-milling, from 80 to 90 per cent. of the gold being saved by amalgamation, while from 10 to 20 per cent. of it is found associated with sulphur or iron-pyrites. The cost of treating the latter compounds, however, is comparatively small. The quartz occurs in lenticular and also in true fissure-veins, the former being bedded in walls of green chloritic and hornblendic schist, and the latter in walls of eruptive granite or gneiss.

After referring to various successful operations under way in the region, the writer enumerates its advantages as follows:—(1) The ore is practically all free-milling, and from actual tests of the gold has averaged about £3 2s. 6d. (15 dollars) to the ton, while the cost of working and treating is estimated to be only 6s. 3d. (1½ dollars) to 17s. (4 dollars) per ton. (2) There is abundance of water for power and other purposes. The whole region is a network of lakes and streams, which afford excellent means of communication and transportation. The power-resources are almost unlimited. As an example, the Keewatin Power Company is installing one of the greatest water-power plants in the world. By the erection of an immense dam they have converted the Lake of the Woods into a reservoir 3,000 square miles in extent. (3) There is abundance of timber for both building and fuel purposes. As fuel, it can be laid down at the mines at a cost not exceeding 6s. 3d. (1½ dollars) per cord, and it is also relatively cheap for building purposes.

The climate is, on the whole, very good, though very cold in winter. Mining operations are carried on all the year round. As a field for labour, wages are good and living expenses comparatively small. The mining laws are liberal. And lastly, while the whole region is principally a gold-producer, good iron-ores have been found in both the Rainy River and Thunder Bay districts, and in the latter, silver, copper and lead have also been found.

X. Y. Z.

LEWIS RIVER COPPER DISTRICT, YUKON TERRITORY.

Lewis River Copper District, Yukon Territory. By W. M. Brewer. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxix., page* 376, *with a map.*

On July 5th, 1898, Mr. John McIntyre discovered the out-croppings of bornite and copper carbonates about 3½ miles distant from White-horse rapids on the Lewis river. The geological formation is principally granite and limestone, with some felsite-dykes. The outcrops, portions of which are very high-grade bornite-ore, are of enormous extent, and indicate the occurrence of very extensive bodies of copper-ore. These outcrops usually occur at the contact, either between limestone and felsite, or between

granite and limestone. The outcrop is described as hæmatite, impregnated with malachite and azurite-crystals. The malachite assays about 17 per cent. of copper, while the bornite carries as high as 64 per cent. The majority of the assays yield both gold and silver values. The timber and water-supply of the district are fairly good, and ample for all purposes for some time to come. The mineral zone in which these discoveries have been made is apparently continuous for a long distance westward.

X. Y. Z.

CERULEITE: A COPPER-ARSENIC MINERAL FOUND IN CHILE.

Sur une Nouvelle Espèce Minérale: la Céruléite. By H. DUFET. *Bulletin de la Société Française de Minéralogie*, 1900, *vol. xxiii., pages* 147-150.

The mineral was found by the author among a number of specimens brought from the Emma Luisa gold-mine at Huanaco, province of Taltal, Chile. It is of a turquoise-blue colour, of clayey aspect in the mass, consisting of numerous minute rod-like crystals. The specific gravity is 2·803, and chemical analysis shows that the mineral is a hydrated arseniate of copper and alumina corresponding exactly to the formula $CuO, 2Al_2O_3, As_2O_5 + 8H_2O$. It is soluble in nitric acid and hydrochloric acid; but a concentrated solution of ammonia, which attacks most copper arseniates, has no action on this particular mineral. Ceruleite is associated with a white clay, which proves to be a hydrated silicate of alumina, containing about 2 per cent. of arsenic pentoxide.

The characteristic mode of occurrence of the Huanaco gold is shown in both the ceruleite and the clay: the precious metal is found (in the proportion of 1 per cent.) in small flakes, arranged in parallel lines along certain planes which traverse the ceruleite, and dispersed in the mass of the white clay or encrusting fissures in it.

L. L. B.

COPPER-ORES OF CERRO DE PASCO, PERU.

Le Gisement de Cerro de Pasco, Pérou. By L. GASCUEL. *Annales des Mines*, 1900, *series* 9, *vol. xvii., pages* 660-681, *and one plate.*

Cerro de Pasco is situated in a kind of basin-shaped depression at an average altitude of 14,000 feet among the high plateaux of the Andes, in south latitude 10 degrees 43 minutes and west longitude 75 degrees. It is 186 miles north-east of Lima as the crow flies. In this depression, several rivers belonging to the Amazon watershed take their rise, among them being the Huallaga, one of the most considerable tributaries of the Maranhao. A railway journey of 12 hours from Lima carries the traveller up to Oroya, at the southern extremity of the Pasco plateau, whence it is a two days' journey on horseback to Cerro.

The ore-deposits of this region were worked for silver, from the date of their discovery in 1630 up to within the last few years. But falling prices, the drowning of several of the mines, and their general bad condition as the result of unmethodical and wasteful working, had combined to accelerate the decay of the silver-mining industry of Cerro de Pasco, when, about midsummer 1898, a mine-owner, more enterprising than his fellows, despatched for sale to Europe a few tons of the hitherto despised and neglected copper-ores. These proved to be very rich, and secured a high price: consequently there is now a great revival of mining industry at Cerro, with the difference that

claims are worked for copper instead of silver. The two most important ore-bodies are essentially veins at the contact between eruptive and sedimentary rocks; some considerable veins occur also in the dark-blue Cretaceous limestones of the neighbourhood, and a great number of parallel veins of less importance in the dacite or quartz-andesite. On the whole, the Cerro-de-Pasco ores are the result of the infilling of numerous fissures in the contact-zone by very hot siliceous waters charged with metalliferous substances, a process of infiltration which accompanied, or followed close upon, the welling-up of the eruptives and the formation of the fissures. Not only did the siliceous fluid fill these up, but it (or its vapours) mineralized and metamorphosed the surrounding rocks over a periphery the extent of which varied according to the permeability and facility of decomposition of the rocks.

The outcrop of the ore-bodies consists of a very impure quartz, highly ferruginous, and full of pulverized débris of the country-rock. Atmospheric agencies have done their work in breaking down the metallic sulphides, and the copper-ores now got have been produced by complex chemical reactions between waters charged with cupric sulphate (the oxidation-product of the chalcopyrite) and the various substances met with as these meteoric waters percolated downward through the rocks. So it comes about that the richest and most extensive masses of copper-ore occur at or near those points where the richest silver-ores were formerly found.

The present annual production of silver from Cerro de Pasco is at most 643,000 ounces troy, the greater part of which is got by treating the old residues: these contain from 3 to 5 parts of silver per 10,000. Half-a-century ago the annual production was four or five times as great. By adding hyposulphite of soda to the *torta* (after one day's trampling by horses), and mercury on the third day, metallic silver is got out of the amalgam after 4 days, whereas the old system of *patio* treatment took at least 50 days. It is true that the new method does not exhaust the ore of its silver quite so thoroughly as the old.

The cupriferous ores now so actively worked are complex sulphides, containing besides copper, variable proportions of arsenic, antimony, iron, lead, zinc, bismuth, and a trace of silver, together with much silica. They vary much in texture, being in some cases a mere pulverulent earth which blackens the fingers, in others an apparently half-molten, extremely hard, black rock. Their average content in copper is 20 per cent., carefully picked lots yielding 40 to 50 per cent. These sulphuretted ores are termed *metal negre*, while the term *metal de color* is applied to the oxidized ores met with in some parts of the district. The latter comprise carbonates, sulphates, black and red copper-oxides, and small quantities of native copper with which some native silver is rarely associated. The copper-content of the *metal de color* also averages 20 per cent., but it varies up to a maximum of 60 or 70 per cent.

At present the monthly output of copper-ore in the Cerro de Pasco district amounts to 2,500 tons: half or more of this quantity is rich ore (assaying to a minimum of 25 to 30 per cent.), which it pays to export. A small portion of the remainder is converted into matte by a single-fusion process in reverberatory furnaces recently built at Cerro.

The author thinks that it will never be possible to sink shafts or drive regular galleries on the European plan in these old mines, as they were so unmethodically and wastefully worked during two centuries and a half that they now resemble a huge warren, full of unfathomed cavities and broken-down pits blocked up with slipped masses of rock and earth. Of course, no old plans of workings are extant, if they ever existed. The underground

mining is done by natives (Peruvian Indians) on the piecework system: the maximum cost of labour works out at about 12s. per metric ton of ore, and the average cost of the ore brought to bank is 10s. per ton. The only other charges are the State tax of £3 10s. per annum for each mine, and the salary of a white overseer (?) varying from £6 to £8 per month.

In conclusion, the author points out that the continued prosperity of the Cerro de Pasco mineral industry really depends on the deeper parts of the deposit, which are hitherto untouched. These it will be possible to explore and win on a rational system. No exploration-work has so far been done in them, but it is known that they will require heavy drainage: the initial expenditure attendant on the opening up of deep-level mines will, therefore, be great. On the other hand, it may be mentioned that within a radius of 30 miles round Cerro are extensive deposits of coal, merely the surface of which has been scratched so far. L. L. B.

NOME GOLD-FIELDS, ALASKA.

(1) *Some Notes on Nome, Alaska.* *By* PAUL F. TRAVERS. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix., pages* 105-106, *with* 2 *illustrations in the text.*

The Nome, Alaska, gold-field was discovered in 1898. The place was then named Anvil City, but was afterwards renamed Nome. A recorder's office was established on the shore, and 1,250 claims staked out by power of attorney, but the writer believes that 1,200 of these claims are fictitious. A claim covers 1,320 feet by 660 feet or an area of 20 acres. Practically, it is always winter at Nome, and it is wet and foggy at all times. The beach is free to everyone, as the Government will not grant locations thereon. It recognizes squatter rights and protects miners while they work. The gold is about evenly distributed in this beach-sand, for a distance of 100 miles, and will pay on an average £4 (20 dollars) a day to a man with a rocker. X. Y. Z.

(2) *Gold and Gold-bearing Sands from Nome, Alaska.* *By* OLIVER ROBERTS. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix., page* 104.

The gold is very fine, and as soon as it comes in contact with water, it rises to the surface as leaf-gold and floats off. It does not amalgamate readily, and it will apparently be necessary to work the concentrates by the cyanide process. In that case, they must be taken to fresh water, as the cyanide process cannot be worked with sea-water. Fine copper sulphides in the concentrates will foul the potassium cyanide and prevent it from dissolving the gold. The subjoined table gives the results of assays made by the writer:—

	Gold per Ton. Ounces.	Value per Ton. £ s. d.	Dollars.
1. Concentrates from beach-sand between high and low water-mark	26·30	113 6 0	543·62
2. Concentrates from Nome	87·50	377 17 0	1,808·62
3. Sand, ballast of ship *Albion*	0·01	0 0 10	0·21
4. Do., ballast of another ship	0·01	0 0 10	0·21
5. Do., brought from Nome in sack ...	0·25	1 1 6	5·16
6. Do., do. do. ...	14·60	62 17 0	301·78
7. Do., from No. 9 claim, Glacier Creek. This sand concentrates up to 14·8 per cent.	39·00	168 7 0	808·13
8. Coarse stuff. Schist, slate, and quartz pulverised	0·50	2 3 0	10·33
9. Gates and Jaques claim, washed in pan with quicksilver	105·07	452 9 0	2,171·71

X. Y. Z.

PETROLEUM IN CALIFORNIA.

The Genesis of Petroleum and Asphaltum in California. By A. S. Cooper. *California State Mining Bureau, Bulletin No.* 16, 1899, *pages* 1-89.

This paper is partly a theoretical discussion of the subject indicated by its title, and partly an elementary treatise on prospecting for mineral oils and allied substances. Incidentally, a considerable amount of information is given as to the stratigraphical conditions of many Californian localities at which petroleum and asphalt are known to occur. All the coals, lignites, and carbonaceous shales in that state are of Cretaceous or Tertiary age, and the known accumulations of petroleum are found in the same rocks, where these are folded into domes and anticlinal arches, and where they consist of more or less porous rocks such as soft shales and sandstones. The petroleum has, however, no connexion with the above-mentioned coals, etc., but has migrated to the positions which it now occupies from areas where carbonaceous deposits (chiefly shales) have been metamorphosed. It is the heat developed during the alteration of these rocks which, by distillation of the carbonaceous matter, has produced the bitumens of the olefine series with an asphalt-base which are characteristic of California.* The distilled products have circulated away from the metamorphic beds upward into the unaltered strata, and are now situated wherever their rise has been stopped by impervious layers of rock. In no case, the author thinks, are they of animal origin. All are derived from land or sea-plants. The unaltered rocks are those in which alone petroleum should be sought, their actual age being of no significance. The presence of natural gas is a very favourable indication. Surface-subsidences are also indications of value, but the oil discovered beneath them is usually thick and heavy. White leached shales and sandstones at the surface often overlie bituminous deposits. The axes of anticlines are necessarily favourably situated for trials, but those anticlines which are most likely to cover valuable oil-deposits are the minor ones running in many various directions, rather than the main lines of saddle-folds which, in California, run north-west and south-east and are denuded along their ridges, so as to expose the barren metamorphic rocks. Nevertheless, visible seepages of oil are more frequently met with along the flanks of the main anticlines. The oil-bearing Tertiary and Cretaceous beds are less denuded and thicker in southern California than in the north, and they also occupy lower ground: hence there is greater storage-room for the oil and asphalts in the south. The Miocene strata are the richest, but the bitumens —either gaseous, fluid, viscous or solid, in superficial alluvia, in veins or in porous or fissured rocks—may, as already stated, occur in non-metamorphic sedimentary formations of any age.

The paper is illustrated by 29 cuts, many of which are instructive plano-sections, *i.e.* combinations of longitudinal sections in two directions with a birdseye sketch of the surface.

In his last paragraph entitled "Some of the Fallacies," the author says: "Clairvoyants can see as far into a millstone as any one, but no farther. Divining-rods were first used to detect perjurers, but since liars have commenced to use them they have lost their virtue and are of no value."

G. A. L.

* The corresponding substances in Russia belong chiefly to the naphthene series, and those of Pennsylvania to the paraffin series with a paraffin base.

BUTTE MINING DISTRICT, MONTANA.

Butte Mining District: Its Geology and History, and a Description of the Various Ores from which its Output is derived. By PROF. ARTHUR LAKES. *Mines and Minerals*, 1900, *vol. xx., pages* 348-350, *with map and sections.*

Up to 1897, the value of the mineral products of Butte was estimated at £60,000,000 ($300,000,000). At present, Butte furnishes 28 per cent. of the copper-products of the world, and of this over one-half is produced by the Anaconda company; gold furnishes about 3 per cent. of the value of the total product; and silver is now a by-product of copper mining.

The copper-ores are found in very basic granite. The silver-ores occur both in granite and in very acid aplite. Quartz-porphyry occurs locally in dykes in the copper area. The silver and copper deposits both contain a little gold. The cupriferous veins always carry silver, and many were originally opened as silver-mines, while towards the west, in most of the veins, is a gradual decrease of the copper-bearing minerals, so that the ores finally become more valuable for silver and gold than for copper. The copper-ores occupy a central position in the eastern half of the district. The Alice and Lexington mines are 1,500 feet deep; other mines in the silver belt are from 400 to 800 feet deep; and most of the large copper-mines vary from 1,000 to 1,500 feet.

Other minerals are numerous, including iron- and copper-pyrites, bornite, chalcocite, enargite, zincblende, rhodocroisite, rhodonite, covellite, argentite, native silver, pyrargyrite, hübnerite, gypsum, sericite, with various oxidation products of these. X. Y. Z.

DANGEROUS OUTCROPS IN PENNSYLVANIA.

Dangerous Outcrops in Pennsylvania. By G. M. WILLIAMS. *Report of the Mines Inspector, Fourth Anthracite District, Wyoming, U.S.A., for* 1899.

Great danger in this district is presented by the possibility of a working mine striking a deep pothole or crevice, or the outcropping of a coal-seam against overlying quicksands. Evidently streams of water rushed in torrents for ages over the coal-basin whilst it was yet a shallow valley, washing away large areas of the softer rocks and edges of coal-seams, and producing deep gorges, craggy precipices, and potholes. Subsequently, the bottom of the valley seems to have slowly subsided for several hundred feet below the level of the then existing water-outlets. Owing to this great subsidence, this valley became a deep lake, with the river flowing through it. During the ages of its existence as a lake, the river-floods passing through brought the detritus of other regions: sand, clay and pebbles, and deposited it in the lake to a depth of several hundred feet. Thus every hollow, gorge, channel, and coal-outcrop is buried deep under the gravelly deposit. Subsequently, the river slowly grinding down the inlet-gap at Pittston and the outlet-gap at Nantichoke, the standing water of the lake ran out, and finally the lake disappeared. Since then the river and every small stream have been wearing down and eroding their channels through the gravel to their present level. To-day, a large number of high sand-hills dot the valley, and a varying depth of gravel is found everywhere filling the hollows where the surface of the rocks below is lower than the present beds of the streams. The outcrops of the coal-seams are in many instances buried under this gravel, and wherever the gravel is at a lower level than the streams, it is saturated and flows as freely as water, so that the mining of the coal becomes very dangerous.

Hitherto, no means has been discovered by which the exact outline of a coal-outcrop or a crevice or pothole can be located under the detritus, which eliminates all traces of the contour of the rock-surface. The only means hitherto used to ascertain the depth of gravel and thickness of rock overlying seams is by boring, but the area so tested is too small to yield very definite information. A dangerous crevice or pothole may exist within a few feet of a bore-hole and not be discovered. The coal-mining companies are boring test-holes from the surface in advance of the workings, and the mine-surveys determine the relative elevation of the workings in the mine, so that the thickness of rock separating the seam from the quicksand may be calculated. One borehole proved the wash to be over 300 feet deep, showing that the sand-deposit was of much greater depth than had formerly been supposed. Where a dangerous depth of gravel exists over the rock, it is usual to leave the coal unworked where the solid strata overlying the seam are less than 100 feet thick.

Notwithstanding such precautions, large bodies of quicksand broke into three of the mines during 1899. Fortunately no lives were lost, but this was due to existing conditions rather than to the precautions taken. After describing some of the accidents arising from this cause, the writer remarks that from Glen Lyon to Nantichoke, the outcrops of all the coal-seams except the two lowest are buried under depths of gravel up to 170 feet thick. On the Glen Lyon estate, 15 diamond bore-holes have been made from the surface, 294 test-holes with pipe and jumper, 2 culm-holes, and 3 holes for signals. These and other holes have proved that a deep channel filled with detritus to a depth of 100 to 260 feet extends from Glen Lyon to the Gap at Nantichoke. There is ample proof that, no matter how numerous are the bore-holes, they cannot cover the field so as to furnish absolute security against accidents. But, on the other hand, the writer asserts that if the holes had not been bored, many lives and mines would have been lost. X. Y. Z.

GILSONITE IN UTAH.

The Hydrocarbons of Eastern Utah, with Special Reference to the Deposits of Ozokerite, Gilsonite and Elaterite. By DON MAGUIRE. *Mines and Minerals*, 1900, *vol. xx., pages* 398-400, *with map and* 3 *illustrations.*

About 1881, during the projection of the Rio Grande Western Railroad through Eastern Utah, samples of a black, tough substance, very much like guttapercha, were found, and also a more brittle substance with a most resplendent fracture when broken. The latter substance proved to be a very dry and pure asphaltum; it was tested by Mr. Samuel Gilson, and the mineral was thereafter named gilsonite. Of all the hydrocarbons of Eastern Utah, gilsonite is undoubtedly the most valuable, both on account of its quantity, and the successful way in which it is manufactured into varnishes, lacquers, and mineral paints for steel and woodwork of every description. Gilsonite at first sold for £24 (120 dollars) per ton, but the mineral now sells at Price Station for about £12 (60 dollars) per ton.

The gilsonite-deposit worked near Fort Duchesne is a fissure-vein, 6 feet wide, very regular, cutting the red sandstone-formation of the country from south-east to north-west. All the veins run across the country in the same direction, and the vein is invariably a vertical fissure. Without doubt, this pure bright asphaltum came up from below, in a liquid state. As it comes from the mine, gilsonite does not require sorting or classifying, for it is

dry, black, and pure. The percentage composition of gilsonite is as follows: Carbon, 78; hydrogen, 11; oxygen, 8; nitrogen, 0·4; ash, 0·2; and loss, during analysis, 2·4. X. Y. Z.

SILVER-BEARING SANDSTONES OF SOUTHERN UTAH.

Silver-bearing Sandstones of Southern Utah: A Description of one of the few Localities where Silver is found in a Sandstone Formation. By DON MAGUIRE. *Mines and Minerals*, 1900, *vol. xx., pages* 323-324.

Silver in paying quantities occurs in sandstone at Silver Reef, Washington County, Utah. In 1873, Mr. John Barbee discovered silver in a sandstone-reef near the town of Leeds, about 15 miles north-east of St. George, Washington county. Investigation proved that the country was made up of successive sandstone-reefs, each of which carried more or less silver, some of them being low in value, while others ran to 1,000 ounces per ton. A small mill was constructed, and in a short time was producing silver ingots. By 1875, five mills were employed in treating the ore, and about 1,000 men were at work mining and milling.

The reefs containing silver showed values along their bedding-planes, and the rich mineralization extends from a few inches up to 2 feet in each of the adjoining strata. Usually, however, the highest values lay along the contact, and at times extensive lenses of ore would exist in such places chambering into several feet at their widest, and tapering down to the thickness of a knifeblade at either end. The silver taken from the eastern workings of the district was usually 0·985 fine; and from the western workings near the town, it was only 0·850, as there was some copper present. In 1883, a strike, called by the miners' union, shut down the principal mines, and the decline in the price of silver beginning soon after, the mines did not resume work.

There are about 10 square miles of mineral land, and only the surface of about 1 square mile has been prospected. North-east of the town of Silver Reef lies what has long been recognized as the richest part of the area, but owing to the fact that water is encountered at the depth of a few feet in this part of the camp, no work was ever done. X. Y. Z.

COAL-EXPLOSIONS AT HAUSHAM, BAVARIA.*

Ueber Störungen und Eigenartige Druckerscheinungen (sogenannt "Pfeilerschüsse" oder "Kohlenstoss-explosionen") der Oberbayerischen Tertiären Kohlenmulde auf Grube Hausham. By KARL BAUMGARTNER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1900, *vol. xlviii., pages* 461-466, 476-482, *and* 489-493, *with* 2 *plates.*

The author first gives an outline of the conditions prevalent in the upper Bavarian coal-field:—there are two workable seams of very inferior quality, containing much dirt, and one of them is split by a band of variable thickness, with the result that they leave much ash. Their chief value lies in their position, all possibility of competition being killed by the cost of transport. The thick seam varies from 2½ feet to 4½ feet (70 to 130 centimetres) in thickness, and the thin seam from 1½ to 2½ feet (45 to 70 centimetres); they lie at a very high angle, in some cases being vertical. The seams are dislocated locally by small troubles, which seldom throw more

* *Trans. Inst. M.E.*, vol. xix., page 527.

than the thickness of the seam, and mostly dip to the north; the strikes of these troubles are seldom more than 1,300 to 2,000 feet (400 to 600 metres) in length, and are parallel. The author, after examination of the direction, etc., of these troubles, makes the deduction that they are due to a pressure from the south. The roof of the seams is framey, falling at intervals in large masses, and the floor is fairly hard. Gas issues from above and below the seams and at the troubles, but never out of the coal-seam.

The coal is worked by galleries driven on the strike of the seam at different levels, connections being made by inclines.

There is a marked difference in the nature of the coal near the troubles and that in the undisturbed areas. In the first, the coal is soft, does not require nicking, and can be hewn without danger; whereas, in the second, the coal is still more easily hewn, but with danger, as the least kirving is sufficient to cause the coal to crack and burst away, often in such large masses as to endanger the life of the hewer. The author quotes one case where 12 men were buried alive, but rescued with difficulty, and several men have lost their lives in this manner.

The bursting away or explosion of the coal is due, in the author's opinion, to the great pressure, and he endeavours to support this theory on the grounds that the only places where the coal is not liable to explode are in the neighbourhood of troubles, which have at their formation eased the pressure. Another point with reference to this bursting of the coal is that an explosion in the pit produces a shock like that of a small earthquake at bank for several miles round, accompanied by rumbling noises. At the same time, the men in other districts of the pit are not aware of the occurrence, while in the affected area the face falls and the roads are lost. This points to the sound not travelling well in the seam, but rather to its being propagated in a direction at right angles to the seam's strike. As long as the coal is not kirved or the action of the pressure started by any other means, the danger is not apparent, but the least interference with the coal causes it to begin to work.

The author describes some of the precautions that are adopted at the face to minimize the chance of accident in the event of the coal bursting away. In the thick seam, kirving was found to be too dangerous and shooting had to be substituted. When the shots are fired two distinct reports are heard, the first being that of the shot, and the second the crack of the released pressure beginning its work. It must be understood that this danger from the explosion of the coal is greatest in the thick seam and very slight in the thin one, as the packing in the thin seam could be more efficiently done; and this was the means of finding a more or less successful remedy for the danger. The experiment was tried of goafing the thin seam, preparatory to any work in the thick seam: the pressure was then found to spend itself more or less in compressing the packed goaf in the thin seam, with the result that the thick seam could be worked with safety. Unfortunately, the thin seam is not everywhere workable, by reason of a thickening band in the middle.

The author summarizes his conclusions as follows:—(*a*) the driving of many advance roads or winnings is dangerous; (*b*) good packing is essential; (*c*) it is undesirable to take out large areas of coal at one time; (*d*) a very gradual advance of the face is recommended; (*e*) all roads and inclines should be made in the goaf; and (*f*) the thin seam should be worked in advance of the thick seam. C. H. M.

RHEINLAND LIGNITE-INDUSTRY.

Der Braunkohlenbergbau Rheinlands. By FRED. HEIMAN. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 544-546.

The extended application of electricity as a source of power and light has had the effect of stimulating the lignite-industry in the Rheinland; and a number of the mine-owners have erected generating-stations around Cologne for the supply of electric current. Furthermore, within a radius of about 50 miles, the lignite can be delivered by rail at about 7s. 6d. (7·50 marks) per truck-load, provided the seller contracts to ship 110,000 tons per annum. The lignite mine-owners are thus able to compete with ordinary coal.

In and near Cologne, the consumption of lignite is largely increasing, the fuel being cheap, easy to handle in proper furnaces, and free from clinker. Large deposits of lignite occur in the Erft and Roer valleys, the Eifel, and many parts of the highlands, and the local conditions render mechanical appliances unnecessary for raising the coal. C. S.

COAL-MINING IN THE ASTURIAS, SPAIN.

La Mine Sous-marine d'Arnao. By ALPHONSE DORY. *Publications de la Société des Ingénieurs sortis de l'École Provinciale d'Industrie et des Mines du Hainaut*, 1899-1900, *vol. ix., pages* 54-71, *with* 2 *plates.*

The Arnao coal-field constitutes the most ancient mine in the Asturias, the concession having been granted on November 28th, 1833; and on February 11th, 1854, a concession was granted for establishing zinc-works, which still exist. During the last few years the works have been connected with the Northern Railway of Spain, by a branch to the port of Avilès, San Juan de Nieva; and this line is laid with three rails, so as to permit passage of the small-gauge trucks, while there is accommodation at the port for discharging ore and loading the finished products. The Arnao colliery, which is the only one worked by shafts in the Asturias, produces yearly about 50,000 tons of coal, this quantity being entirely consumed at the zinc-works.

Unlike most Asturian coals, which are friable, dull and iridescent, the Arnao coal, especially that under the sea-bed, is hard, bright and whitish, this tint being due to scales of calcium sulphate covering the coal; and sometimes the surface of the coal has the appearance of concentric rings. Analysis shows that the coal contains from 55 to 60 per cent. of coke, from 39 to 45 per cent. of volatile matter, and from 20 to 6 per cent. of ash, while the proportion of coke without ash varies from 40 to 49 per cent.

Levels from the bottom of the winding-and-pumping shaft have been driven to the boundary of the seam; and on the sea-side of the shaft, owing to the slight thickness of the barren rocks, working is carried on very slowly and with every precaution for preventing subsidences. Gobbing material is sent from the surface, generally at night, by a series of inclines having the same height as the stalls, most of it being obtained from a limestone-quarry; but there is also a gobbing-shaft for sending down sand and pebbles from the sea-shore.

Originally the coal was removed, the roof allowed to fall, and, there being no demand for small coal, a great deal was left in the mine. As the working was carried on without any precautions, underground fires occurred.

The water-tightness of the under-sea portion is attributed to the slowness with which the working is effected and the careful gobbing, to the existence

of certain shale-beds which crack and fissure when pressure comes down on the roof, and afterwards swell on the sea-water percolating into them. When the workings had reached the greatest distance to which they have extended under the sea, there was a slight inburst of water. Analysis showed no trace of salt in the water; but soon afterwards the water became decidedly salt. Owing to this inburst, the under-sea working was abandoned, large pillars of coal being left for its protection. J. W. P.

TURQUOISE MINES OF PERSIA.

The Turquoise Mines of Persia. *By* H. L. Geissel. *Scientific American*, 1900, *vol. lxxxii., page* 246.

About 35 miles from Nishapur, in the Khorassan, are the celebrated turquoise-mines of Persia. They are situated in a mountainous region 5,000 to 6,000 feet above sea-level, and employ about 1,500 persons. The concession covers about 40 square miles, and the tract is exploited by a local chief and banker, who pay an annual rental of nearly £3,000 (14,000 tomans). In former times, the mines appear to have been carefully worked, as remains of vertical shafts for ventilation are to be seen. The present manner of working is primitive in the extreme. The Reish mine is very productive, but the stones are not of first-class quality, though every species of stone finds a sale. Many of the mine-openings are mere burrows, barely large enough to admit a man, and such is the case with the Abdar-rezai mine, which formerly produced the finest stones in the world. Good stones could probably still be discovered, if systematic mining were carried on. The soil seems to be full of turquoise in different stages of development, from a cream-coloured chalky substance to the variously-shaded green and blue gems. The approach of the mines is strewn with fragments of the stones, and the walls and roofs of the galleries are seamed with turquoise composition, but being of bad colour and full of flaws it is valueless. High prices are now paid for stones at Meshed. Some few years ago, fine turquoise of cerulean blue, perfect shape, good size, and flawless, could be bought in Meshed for a few shillings; but, at present, as soon as cut, they are exported direct to Moscow.

X. Y. Z.

GOLD-MINING IN NOVA SCOTIA.

Gold-mining in Nova Scotia. *By* G. W. Stuart. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxx., pages* 309-311, *with* 2 *illustrations.*

Following up Mr. E. R. Faribault's paper on this subject,* the writer gives some interesting practical information. It appears that the smaller quartz-veins usually yield ore in many cases attaining a value of £40 to £400 (200 to 2,000 dollars) of gold per ton. The writer had the rare experience of mining and milling ore from a vein, 6 inches thick, yielding £800 (4,000 dollars) of gold per ton. In working small rich veins, 3 to 5 feet wide, it has frequently been found that the whole of the rock excavated would have paid to mill, even for the free gold it contained, with modern appliances.

As the small rich veins go deeper, less gold is obtained by the free-milling process, but there is strong evidence that this fact is due not so much to diminution of value as to increased refractoriness of the ores. Believing this

* *Trans. Inst. M. E.*, vol. xviii., page 497.

to be the case, a chlorination-plant (the only one in the Province) has been erected by the Brookfield Mining Company and the operating results have been most satisfactory. The vein has retained its width and yield by the chlorination-process down to a depth of 650 feet.

As an illustration of different practical results between old and modern methods, it may be noted that the Libby mine was opened, worked and abandoned in the early days. After a number of years, a modern plant was erected. In 4 years, £80,000 (400,000 dollars) of gold has been obtained. The total cost of mining, milling, concentrating and chlorinating the ore from this vein, 30 inches thick, is 15s. (3·60 dollars) per ton, which includes the cost of development. The yield is £1 13s. 4d. (8 dollars) per ton.

Recently, several plants have been erected capable of going to a considerable depth, and, so far, none have met with disappointment. During the last 25 years, the Lake lode has been worked and abandoned by several small companies in turn. At a depth of 250 feet, it gave the low yield of 8s. 4d. (2 dollars) per ton; at a depth of 540 feet, the lode has increased from 5 to 15 feet wide, and is worth £2 6s. (11 dollars) per ton. The Richardson lode, at Isaac's Harbour, has passed through a similar experience, and is a perfect illustration of the anticlinal system expounded by Mr. Faribault.

The Tunnel or Barrel quartz-mine at East Waverley is, if possible, a yet more perfect illustration of the anticlinal system, more interesting and apparently of far greater value than any of the saddle reefs opened up in the Bendigo district of Australia. For this upper reef at Waverley (the only one of the series yet developed) at a depth of 465 feet has materially increased in both quantity of ore and in values, although at depths between 200 and 300 feet a poor zone of insignificant extent was encountered. X. Y. Z.

NACOSARI MINES, SONORA, MEXICO.

The Nacosari Mines, Mexico. By H. B. Layton. *The Engineering and Mining Journal (New York), 1900, vol. lxix., pages* 678-679 *and* 707, *with* 6 *illustrations.*

The development of the Great Pilares copper-mine and the construction of the big plants connected therewith have been accomplished under conditions, which, considering the size of the undertaking, would have been prohibitive to less determined operators.

The property is situate 98 miles south of Bisbee, Arizona. The elevation of the town site is 4,000 feet above sea-level. Six miles eastward, is Pilares Mountain, 1,200 feet higher than the town, and the great body of ore lies in this mountain. Topographically the mountain is rugged and steep, and great pillars of rock protrude above its crest, hence the name *Pilares.* The ore-body lies in an eruptive belt of trachyte in bird's eye porphyry formation, capped with breccia, with perhaps trachyte as a binder. The ore is chalcopyrite and siliceous rock, although the surface-ore contains considerable black oxide of copper. The constituents of the average ore are: silica, 45·50; alumina, 24·82; iron, 8·50; copper, 8·00; sulphur, 12·25; lime, 0·63; and magnesia, 0·30.

A tunnel, the sixth level, has been driven from the terminus of the railway in Rosaria Cañon, it will tap the main shaft, at a depth of 5,000 feet, and it is being driven by 2 Ingersoll-Sergeant drills. When this tunnel is completed, all ore from above will be lowered and all from below will be hoisted and passed out through this tunnel.

Electricity is used to drive the several departments of the reduction-plant. There are 8 Crossley gas-engines, rated at 110 horsepower, worked by Loomis water-gas. Each engine is belted direct to a 65 kilowatts, 260 volts, shunt-wound direct-current electric generator, at a normal speed of 910 revolutions per minute.

The concentrator-building is a steel-frame sheathed with corrugated iron. The mill is of 400 tons' daily capacity and from mine to ingots, 98 per cent. fine, the ore and metal pass through every operation almost by gravity.

X. Y. Z.

EL REFUGIO MINE, DURANGO, MEXICO.

The Gold Zone of Copalquin, Mexico. *By* FRANK B. FOWLER. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxix., pages* 225-226 *and* 557-558, *with* 4 *illustrations.*

The El Refugio mine was discovered in 1849, and the free-milling ore was treated in *tajonas (arrastras* moved by horizontal water-wheels of primitive construction), and by this crude method yielded as high as 720 pounds of gold and silver electrum during two month's run, which is said to have been for a time the average output, the richest ore yielding 2,000 ounces per ton, and the lowest grade milled 4 ounces of silver and 1 ounce of gold per *carga* (300 pounds). The work of systematic development of the Refugio mine has been resumed since 1897.

The mine is located 1,150 feet (350 metres) above the Copalquin Creek, 3,700 feet (1,130 metres) above sea-level, and its plan of development is that of self-draining tunnels. The ore contains 12½ ounces of silver and 1 ounce of gold per ton.

The continuous process of treatment consists in wet crushing, amalgamation in the batteries by means of chuck-block plates, and concentration of pyrites and silver sulphides upon Frue vanners and Wilfley tables, of a capacity of about 75 tons per day. An automatic gravity cableway, 2½ miles in length, is used for the transmission of ore from the mines to the mills. X. Y. Z.

MINING IN NICARAGUA.

Mining in Nicaragua. *By* THOMAS W. WHITE. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxix., page* 104.

The mineral belt of Rama covers an area from 7 to 12 miles in width and not less than 25 miles in length. Recent assays show that the quartz contains from 12s. to £90 (3 to 450 dollars) of gold per ton with a general average of about £4 10s. (22½ dollars) per ton. The mining district extends from the river bank back into the mountains, making it only necessary to pack provisions from ½ to 3 miles. Indian, negro, and native labour are paid £2 to £3 (10 to 15 dollars) per month and board. The country is healthy, the average daily temperature in the mining camps being about 74° Fahr. at night and 80° Fahr. at noon. X. Y. Z.

FATAL ACCIDENTS IN COAL-MINES IN NORTH AMERICA.

Fatal Accidents in Coal-mining in North America. By F. L. HOFFMAN. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxx., page* 608.

In 1899, the death-rate in the coal-mines of North America was the highest since 1891. A number of detailed tables are given, but the results are summarized in the following table, covering the decade ending with 1899, and embracing the whole area of North America, including Canada.

Year.	No. of Employees.	No. killed.	Death-rate per 1,000 Employees.
1890	288,205	701	2·43
1891	325,840	1,076	3·30
1892	342,744	859	2·51
1893	374,017	919	2·46
1894	377,626	934	2·47
1895	387,303	1,020	2·63
1896	391,990	1,091	2·78
1897	393,025	909	2·31
1898	395,553	1,004	2·54
1899	401,868	1,200	2·99
Totals	3,678,171	9,713	Average 2·64

The highest rate was attained in the State of Washington, where from 1892 to 1899, the average annual fatality-rate per 1,000 persons employed reached 9·62; Kentucky furnishes the lowest rate for the decade, namely, 1·22; in Pennsylvania, the decennial rate for the bituminous coal-mines was 2·08, and that for the anthracite-mines 3·18.

The writer remarks that, while coal-mining must continue to be regarded as one of the most dangerous in the category of hazardous employments, it would be erroneous to conclude that the mining industry is more dangerous than any other. In support of this statement, he submits, for the same decade, the fatality-returns for the railway-service of the United States. These show that the death-rate per 1,000 is exactly the same for railway-employees as it is for coal-miners. In both cases, the decennial death-rate is 2·64. It is, however, worthy of consideration that, while previous to 1894, the railway death-rate was the higher, the coal-mining death-rate has been the higher of the two ever since that year. X. Y. Z.

CRIPPLE CREEK DISTRICT, COLORADO.

The Cripple Creek District, Colorado: V. Some of the Mines; and VI. the Power-plants. By Dr. S. F. HAZLEHURST. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxx., pages* 635-636, 669-670, *with* 4 *illustrations.*

The plant of the Colorado Electric Power Company is situated at Cañon City, whence the current is transmitted by means of No. 3 Brown and Sharp gauge wire to two power-houses, from which it is distributed throughout the Cripple Creek district. Mershon glass insulators are used for the support of the 20,000 volts wires. At Cañon City, the current is generated by Westinghouse alternating-current dynamos adapted for operating the Tesla three-phase system, which is the means of transmission used. Each machine has its armature mounted on the shaft of a Hamilton-Corliss cross compound

condensing engine, and the combination of engine and dynamo forms a generating unit. There are three of these units at present, one of which is kept as a reserve in case of emergency. For exciting the fields of the main dynamos there are two Kodak exciters, each capable of exciting all three of the main dynamos: one of these being reserved for cases of emergency. The engines are steamed from a battery of Heine water-tube boilers; the exhaust from the engines that drive the main dynamos is sent to a surface-condenser, while that from the pumps and exciter-engines passes through feed-water heaters. The electric and steam-machinery is capable of supplying 2,000 horsepower.

The current from the generators is transformed from 500 to 20,000 volts, at which pressure it is delivered to the transmission-line to the Cripple Creek district 24 miles away. At the sub-stations in the district, the 20,000 volts current is again transformed back to 500 volts, at which pressure it is delivered to the mines for any use to which steam-power can be put. The company owns and rents 63 electric hoists, in addition to those owned by the mines and individuals. These range from 5 to 30 horsepower, and are all of the induction-type. The transformers at the sub-stations reduce the pressure to 6,000 volts, at which pressure it is transmitted to the District Railroad, where it is again reduced by step-down transformers from 6,000 to 365 volts, at which voltage it passes to the 200 kilowatts rotary transformers, where it is transformed to 500 volts direct current for use on the railroad system. Wurts lightning-arresters are used.

The Gold Exploration and Tunnel Company began its operations on the west side of Gold Hill with the view of pushing its workings to the various ore-producing points in the district and allowing development-work to be carried on through the medium of the tunnel. The owners of claims through which the tunnel passes have the opportunity of seeing the condition of their property at a known depth, and they can pursue development-work on payment to the tunnel company of a fair rental for the advantages offered them. The projected extent of the tunnel is 17½ miles, including main line and extensions, the main line proper being 3 miles in length. The depths at which the tunnel will pass beneath the principal points in the district vary from 773 to 1,498 feet. The tunnel is now 4,500 feet in solid rock, and no timbering has been necessary. No water has yet been encountered, but provision is made for that event by a capacious box-drain beneath the car-tracks. The grade of the tunnel is 1 in 200. Haulage at present is by mules, but a compressed-air engine is ready for use. Some small veins have been cut in the tunnel, and advantage has been taken by the owners thereof to prosecute development-work. X. Y. Z.

BROWN IRON-ORES OF GEORGIA.

Brown Iron-Ores of Georgia. *By* S. W. McCallie, *Assistant State Geologist. The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix., pages* 255-256, *with* 2 *illustrations.*

The brown iron-ores of Georgia are confined mainly to the north-western part of the State (Polk and Barton counties) in the Palæozoic area. These deposits occur chiefly in the Lower Silurian, but are also found associated with the Carboniferous and Cambrian deposits.

The most abundant iron-ore deposits of the Lower Silurian exist in the Knox Dolomite series—an extensive magnesian limestone with a maximum

thickness of over 3,000 feet. This formation often contains an abundance of chert, and usually gives rise to low, well-rounded ridges, along which the iron-ore deposits most generally occur, in pockets in the residual clays that have resulted from the weathering of the limestones. In connection with these ores, chert and manganese are found, but in the more valuable deposits these impurities are rarely present in quantities sufficient to affect the commercial value of the ores. In some cases, the banks contain a few tons, whilst others have produced several thousand carloads. Sometimes the ore is honeycombed, but more generally it is compact and free from all foreign material. In the last few years, steam-shovels and logwashers have been introduced, and in some instances the cost of mining, washing and placing the ore on the cars ready for shipment to the furnaces, has been reduced to 1s. 8d. (40 cents.) per ton. With few exceptions, the ores are mined by open cuts, varying in depth from 5 to 60 feet or to water-level. At Oredell, in Etna valley, a bore-hole proved that the brown ores exist at 175 feet below the valley surface. In the vicinity of Cedartown, valuable deposits have been worked to the depth of 70 feet. It seems probable that in many cases these deposits are limited only by the thickness of the magnesian limestone which underlies the residual clays wherein the ores occur. The locations of the ore-deposits, as a general rule, are indicated by the occurrence of more or less float-ore strewn upon the surface; but the quantity of ore on the surface is not always a criterion of the quantity below. The ores of the Knox Dolomite series run high in metallic iron, and low in sulphur and phosphorus. From a number of analyses made, the following results were obtained: Iron, from 48·45 to 51·10; manganese, from 0·2 to 5·6; silica, from 2·4 to 7·87; phosphorus, from 0·147 to 0·858. Sometimes these brown ores yield a higher percentage of iron than the theoretical limonite, evidently owing to the partial metamorphism shown by the red colour of the ore.

The iron-ores of the Cambrian formation occur associated with sandstone, mica-schists, and slates, and differ somewhat in character and mode of occurrence from those of the Knox Dolomite series. In some cases, they have been metamorphosed so as to partake of the nature of true hæmatite. In the neighbourhood of Emerson, the deposits often assume the character of veins. In the northern part of Barton county, the ores partake of the nature of blanket deposits, valuable because of their richness and the cheapness with which they can be mined. In other localities, the ores occur in pockets, as in the Knox Dolomite series. The chemical analyses of the Cambrian ores are similar to those of the Knox Dolomite, the cherty material in the latter being replaced by siliceous material in the former.

The Carboniferous iron-ores are apparently not so extensive or valuable as the Silurian or Cambrian deposits. Nevertheless they are of considerable economic importance, especially those of the Sugar valley district.

Besides the brown-ore deposits of the Palæozoic area, there are also to be found in north-western Georgia, in the Crystalline-schist area, valuable deposits of brown-ores which are so far practically undeveloped.

X. Y. Z.

RAMSHORN COPPER-SILVER MINE, IDAHO.

The Deepest Mine in Idaho. *By* R. N. Bell. *Mines and Minerals*, 1900, *vol. xxi., pages* 174-176.

The Ramshorn mine of Bayhorse, Custer county, has the reputation of being the deepest and best-developed copper-silver mine in Idaho. The cañon in which the Ramshorn and most of the other big mines of the district

are situated is deep and narrow, presenting an elaborate cross-section of the geology of the region. The formations embrace various horizons, from the Carboniferous blue limestone down to the Archæan granite. Associated with them are found enormous intrusions of diorite, syenite, quartz-porphyry, and more recent igneous rocks, together with the usual evidence of faulting, folding, and fissuring usually accompanying these formations. This is a combination of conditions which is universally recognized as the most reliable indication of the presence of great mineral wealth.

The Ramshorn vein is a compound fissure cutting across the bedding-planes of a thick series of metamorphic slates. It courses north-and-south, and dips westward at an inclination of about 50 degrees. The pay-streaks occur on either wall of a zone of crushed slate: in the upper workings they are about 60 feet apart and appear like two closely parallel veins, but they approach each other as they extend downward; and in the lower levels they are 20 feet apart, and probably unite at a greater depth as one strong vein of pay-ore. The pay-shoots now exposed are from 6 inches to 6 feet thick and carry values of from £5 to £200 (25 to 1,000 dollars) per ton. One shoot of clean grey copper-ore, over 24 inches thick, has an average value of 1,200 ounces of silver and 25 per cent. of copper. These shoots of clean high-grade ore are sometimes found 4 feet wide, and the average of all the ore mined has been over 100 ounces of silver per ton.

The method of development consists of a system of adit-tunnels driven to the vein, at intervals, as it courses down the face of the mountain, and connected underground, with a regular system of rises, chutes and manways. At the mouths of the principal tunnels are substantial ore-bins, arranged to feed a wire-rope tramway, by which they are all connected to the principal storage-bin at the foot of the mountain. The ore carries an excess of free-smelting iron. The longest tunnel on the Ramshorn mine was started several hundred feet above the creek-level and is driven on the vein. It has penetrated the mountain for a distance of 3,000 feet, and at the present face shows a body of ore, nearly 3 feet wide. The steep pitch of the mountain, into which this vein and tunnel course, gives a vertical face-depth of 3,000 feet. The tunnel, with its miles of connections, probably constitutes the deepest development of any ore-vein in the State of Idaho. X.Y.Z.

METHODS OF IRON-MINING IN NORTHERN MINNESOTA.

Methods of Iron-Mining in Northern Minnesota. *By* PROF. F. W. DENTON. *Transactions of the American Institute of Mining Engineers*, 1897, *vol. xxvii., pages* 344-390.

Vermilion Range.—In the Minnesota mine, the ore occurs in lenses dipping north about 70 degrees, and varying in thickness from a few feet to over 100 feet. It is extremely hard and strong, while the walls of green schist or soapstone rock are soft and weak.

The method of mining may be described as "longitudinal overhead stoping with filling." The diamond-drill, run by compressed air, is used, and about 12 holes are drilled in 10 hours. In a stope, 40 feet wide, two holes 24 to 30 feet deep would be made, one pointing a little to the hanging-wall and the other to the foot-wall, and charged with 30 to 50 pounds of 50-per-cent. dynamite, which would dislodge from 500 to 1,000 tons of ore. The cost of diamond-drilling exceeds that of machine percussion-drilling; but the product per foot of hole is much greater with the diamond drill, making the cost

per ton less. The shoots, timbered up through the filling, down which the ore is dropped to the level below, are placed about 30 feet apart, and 100 feet of vertical height is found to be the most economical limit, beyond which it is cheaper to put in another main level. The pumping-plant consists of a somewhat unusual type of direct-acting plunger with fly-wheel, and is fixed underground. It has a lift of 817 feet, and the plunger speed has been increased from 100 feet to 360 feet per minute, by the use of a special form of air-chamber placed over the discharge-valves, and supplied with a constant volume of air. The difficulties of crushing so hard an ore, and the various alterations in the constructive material and working parts of the Blake crusher—to enable it to do its work effectually—are briefly described. The cost of crushing is about 6½d. (13·19 cents) per ton.

The Chandler mine produces a high-grade ore containing 60 to 65 per cent. of iron and 0·048 per cent. of phosphorus. The ore-deposit is supposed to have been originally massive hæmatite, subsequently broken up by natural forces; it lies in a fold or basin, and is covered by a jasper capping. There is a peculiar layer of altered schist, 30 feet thick, between the ore and the unaltered green schist. Considerable difficulty has been experienced with the shafts, the tops of which have been lost, owing to subsidence having extended farther than was anticipated. Inclined shafts have been sunk farther back, to meet the uninjured portion of the original shafts.

The method of mining is known as "sub-drifting": main levels, timbered, 9 feet wide and 7 feet high, are driven at vertical distances of 75 feet apart. Rises are put up every 50 feet along the levels, and out of each of them four sub-drifts are run, separated by 8 feet of ore, and timbered, 6 feet square; the three top sub-drifts are run first, leaving the lower one to strengthen the main level. The sub-drifts being completed, the block of ore is honeycombed with drifts, with vertical pillars, 8 feet high, between each. The pillars are then sliced away, the back caved, and the caved ore wheeled in barrows to ore-shoots leading to the main level below; these ore-shoots are timbered, 4 feet square, and lined with 2 inches planks placed on edge. A modified method is being adopted in the lower levels, to save putting up rises and to use trams instead of wheelbarrows.

Mesabi Range.—The deposits are of great area and relatively small depth, dipping to the south at low angles, and covered with Glacial Drift from 2 to 100 feet thick.

At the Mountain iron-mine, an open cutting is made into the deposit, the ore is loosened by blasting, and quarried by steam-dredges or shovels. A shovel-crew consists of 5 pitmen, an engineer, cranesman, and fireman, and will fill on an average 133 trucks of 26 tons per day of 10 hours or 3,458 tons of ore. Two locomotives are used for each shovel, one to handle the empty truck and the other the loaded trucks. Steam-shovels are also employed for stripping or bearing the ore. The ore contains 64 per cent. of iron, with from 0·045 to 0·065 per cent. of phosphorus.

The Auburn mine is an example of a mine employing underground mining combined with quarrying. The levels are driven with about 60 feet of ore over them. A main drift is run straight from the shaft, with branch-drifts at an angle of 45 degrees. From the drifts, rises are put up 40 feet apart to the top of the ore, which is then worked in the form of a crater; the rises forming the central pipes, down which the ore falls to the level below, whence it is loaded, and hoisted up the shaft. Holes are drilled round the sides of the crater, by driving down 1¼ inches steel rods from 5 to 18 feet long, two to four strikers being employed. The rods often stick fast, and are drawn out by

railroad jacks. The holes are first "chambered" with 3 or 4 sticks of 50-per-cent. dynamite and then charged with 3 to 60 25-pounds kegs of powder. Ropes are provided to prevent the men from being carried down into the rises by the sliding of loose ore on the sides of the craters. Men thus carried into the rises have been rescued, by placing around them barrels or pieces of tube large enough to prevent the ore from smothering them. With this protection they have time to work themselves loose, and can be pulled out.

The ore at the Fayol mine contains 62½ per cent. of iron and 0·038 per cent. of phosphorus. The ore-body is covered by 65 to 90 feet of Glacial Drift. The method of mining is by rooms about 24 feet wide, separated by pillars of the same size. The rooms are carried up 65 feet, are 300 feet long, and are filled in with drift from the surface. The rooms used to be carried up by overhead stoping with square-set timbering, but another method has just been successfully adopted, whereby a rise is put up through the centre of the room to the Glacial Drift. The roof having been securely supported by saddleback timbering, the room is stoped out underhand, and the sides are left entirely free from timber. The ore obtained from these rooms is more cheaply mined, and with a low timber-cost. A description of the shaft, headgear, engines, etc., is given; a special timber-slide for getting timber into the mine is also described.

A detail of some interest in these mines is the use of special underground rooms for thawing dynamite: they are kept warm by steam, and contain lockers for the contract-parties. A. W. G.

WINDBER COLLIERIES, PENNSYLVANIA.

The Largest Collieries in the United States. *By* BURCHAM HARDING. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix., pages* 197-198 *and* 230-232, *with* 9 *illustrations.*

About two years ago in Somerset County, Pennsylvannia, the Berwind-White Coal Mining Company secured the mining rights over 70 square miles.

The seam of coal is about 4 feet thick, and extends for several miles in every direction. The main headings extend from the entrances of the mines in straight lines. At distances of about 315 feet, cross-headings are run at right angles to the main headings, and on each side of the cross-headings rooms are opened up. The roof is supported by pillars in the usual way, until the rooms are cleared and that part of the mine deserted. In course of time, the main headings will extend to 3 and 4 miles and the cross-headings to 2 and 3 miles in length, until they reach the workings of the adjacent mines.

Near the entrances to the mines, power-plants are erected to furnish motive power for all the mining operations. These plants include water-tube boilers, steam-engines, air-compressors, and electric generators.

All the coal is worked by mechanical coal-cutters, operated by compressed air, and the face readily breaks down by the use of explosives. One of these machines does the work of about 20 miners and, compared with hand-labour, increases the output of coal per acre by about 12 per cent. About 100 tons per day is the output from each cutter.

At a short distance from the mine-entrance, the height of the heading is reduced to a little over 4 feet, which suffices for the passage of the electric mine-locomotive with its load of cars. A double track of railroad extends throughout the main heading in each mine. The cost of this method of haulage, taking No. 35 mine as an example, is less than ½d. per ton, the entrance to this mine having a dip of 1 in 40 for 3,000 feet. The rails

extend from the entrance of the mine for about 1,000 feet to the tipple, where the coal is dumped into the railway-cars. On reaching the tipple, the mine-locomotive leaves its train of 45 loaded cars, and returns to the mine with empty cars, the down grade being sufficient to carry the loaded cars to the dumping-places. Five cars are uncoupled at a time, and allowed to run down to the chutes, passing over the weigh-bridge *en route*. Dumping is performed by an improved crossover tilt, and, as the car approaches the chute the operator moves the dumping-lever, the wheels strike a pair of blocks, and the wagon dumps its contents into the chute. At a distance of about 20 feet from the chute, a portion of the right-hand rail is raised about 6 inches, a loaded car approaching the chute passes over this spot, and depresses the rail, which causes the wheel-blocks at the chute to swing outward, and allows the car which has just been emptied to pass onward. The empty car runs down an incline, the momentum acquired carries it up another incline, where its motion is reversed, and it is then automatically switched into the siding for empty cars. As many as 9 cars can be dumped in 1 minute.

The tracks under the tipple are also built upon a grade so as to utilize the force of gravity. All the movements are done by gravity, checked by hand brakes. The railroad-cars have capacities of 30 and 50 tons, and 11 cars can be loaded in 1 hour.

The ventilation at No. 35 mine is effected by a fan, 16 feet in diameter by 6 feet wide, delivering 325,000 cubic feet of air per minute at a water-gauge of 7½ inches.

The power-station of this mine supplies power to 35 mining machines, and 22 pumps, which are served by compressed air; and for 5 mine-locomotives by three 150 kilowatts electric-generators. X. Y. Z.

APPARATUS FOR MEASURING THE DIP OF STRATA IN BORE-HOLE CORES.

Apparat zur absoluten Feststellung des Streichens Kernfähiger Erdschichten. By HERMANN GOTHAN. *Berg- und Huettenmaennische Zeitung*, 1900, *vol. lix., pages* 159-160, *with* 1 *plate.*

As in the apparatus of Köbrich and that of Wolf, a magnetic needle is employed that can be stopped by a train of clockwork; but, in this case, the apparatus is firmly attached to the core in the hole, and therefore gives more reliable results. The magnetic needle is mounted on the apex of the minute-wheel spindle and, on the automatic release of a catch by the train of clockwork at a predetermined time, is forced upward against a rest faced with soft material, in which a point mounted on the needle engages and holds the latter fast. The case of non-magnetic metal enclosing the needle and clockwork is mounted inside the cylinder of the boring-tool, so as to make firm contact with the core; and, when the needle has been fixed, the core is broken off and the whole raised to bank. Here the core is exposed, marked in conformity with certain marks on the cylinder, and mounted in a socket on a turntable, both being also marked, the whole of the marks being set to coincide. The boring-cylinder being removed to expose the dial-plate of the clockwork, the position of the needle is determined by means of plummets, and after releasing the needle, the turntable is revolved until the needle is over the point of the dial-plate at which it was fixed. When this is attained the core is in exactly the same position as it occupied in the bore-hole, and the dip of the strata can be accurately read off. C. S.

THE TESTING OF FLAT PLACER-DEPOSITS BY BORING.

The Testing of Flat Placer-Deposits. By ROBERT NYE. *The Engineering and Mining Journal* (*New York*), 1900, *vol lxx., pages* 37-38.

The successful results obtained during the past few years by the dredge and the steam-shovel in working gold-bearing deposits has caused great interest to be awakened in this branch of placer-mining. There can be no doubt that the best way to test a placer-deposit is by means of shafts, or drifts, or both, if the cost allows. But the writer knows of one case where good results upon this kind of ground were obtained by an auger operated by hand; and, for the same cost as one shaft, a large number of holes were put down, giving a much more accurate contour of the bed-rock. The results from the auger-holes were checked by an occasional shaft, and found to be very accurate. In ground suitable for dredging, however, there is often so much water that shaft-sinking is too expensive; in fact, some dredging-grounds, with all the natural conditions necessary for successful work, contain so much water that to prospect them by shafts would cost more than to put the necessary dredgers upon them. In one case, over £800 (4,000 dollars) was spent in the vain attempt to sink a shaft to bed-rock, which was afterwards shown by a drill-hole to be 27 feet from the surface.

The writer describes the process and the precautions necessary to be observed so as to obtain accurate information. The two main precautions are (1) that the bottom of the pipe must be kept in advance of the point of the drill until bed-rock is reached, and (2) that, when bed-rock is reached, the pipe must be driven into it, or upon it tight enough to shut out all sand and water, and allow of the hole being pumped out clean and dry. The cost per foot of these holes varies with local conditions, and apart from the cost of labour and horse or steam-power, three factors enter into the problem: (1) the time required to put down a hole; (2) the time required to pull out the pipe; and (3) the time required to move the drill. The writer is of opinion that in many cases the use of steam-plant will not be economical. He has prospected ground with a horse-power machine, and found that a move from 100 to 5,000 feet could be made, and the next hole put down, before the steam-power drill could be moved and set up. The writer's experience is that in favourable conditions a hole may be put down at a cost of 3s. 9d. (90 cents) per foot up to 25 feet deep, and in other cases, where the conditions were very unfavourable, the cost rose to 14s. 7d. (3½ dollars) per foot. X.Y.Z.

DULAIT-FORGET ELECTRIC DRILL.

Note sur la Perforatrice Électrique Dulait-Forget. By — CUVELETTE. *Bulletin de la Société de l'Industrie Minérale*, 1900, *series* 3, *vol. xiv., pages* 161-190, *with illustrations in the text and* 3 *plates.*

This electric drill has been employed in the Flaviac mines near Privas, in driving a stone drift some 4,500 feet long. Briefly, the Dulait-Forget drill is composed of three parts: the motor, the flexible shaft, and the drill. The motor, Siemens wound, of the Dulait type, 3½ horsepower, absorbs 30 ampères and 110 volts, and gives a useful effect of 80·25 per cent. The flexible shaft is of the Marotte type. The drill turns and advances at the will of the workman, and gives about 420 blows a minute.

The following plant was erected to drive 3 electric drills: 1 Dulait compound-wound dynamo, 11 kilowatts, 220 volts, 1,100 revolutions per minute,

with the usual fittings, switchboards, etc.; 3 electric drills; 3 carriages with lateral motion for drill and motor; 3 trucks with racks, to convey machines from place to place; 4 copper sheathed ends for the cables; 6 lamps of 16 candle-power; and 3 syringes. The total cost of the plant was about £400, and if the cost of the boilers and tools be added, the price will work out to about £80 per horsepower.

The holes made in one face were from 9 to 11 in number and seldom more than 4 feet (1·20 metres) long; the width of the drills varied from 1¾ to 1¼ inches (46 to 36 millimetres). The number of drills blunted in boring 9 to 11 holes or a total length of about 30 feet (9 metres) in the various rocks was: 40 in the siliceous marls, 70 in the mica-schists, and 100 or more in the quartz.

Each advance of the face required about 8 hours, divided as follows:— Boring, 9 to 11 holes, 2 to 3 hours; firing, waiting and meals, 2 hours; removing stone and squaring up the face, 3 hours; or a total of 8 hours. Consequently, 3 advances might be made each day, but in practice seldom more than 2 were accomplished.

The drift was driven through siliceous marls, mica-schists containing veins of quartz and granite; and hand-labour was alone employed while passing through soft stone.

During one week, 40 feet (12·20 metres) were driven, of which 30·8 feet (9·40 metres) were driven in granite, and the cost was 24s. per foot (96·40 francs per metre). During a previous period the cost was 27s. per foot (113 francs per metre); in another it was 20s. per foot (83·52 francs per metre); and the daily advance in soft rock worked by hand was only 1¼ to 1¼ feet (0·35 and 0·40 metres). C. H. M.

LIQUID AIR AS A BLASTING-AGENT IN MINES.*

Facts versus Claims for Liquid Air. *By* HUDSON MAXIM. *Scientific American* 1900, *vol. lxxxii., page* 163.

After ridiculing the unscientific claims made in some quarters for liquid air, the author remarks that liquid air will be chiefly valuable as a source of oxygen for purposes other than the production of motive power. If it can be produced at, say, 2½d. per gallon, it may be destined to find its most useful application as a blasting-agent for mining purposes. The author recognizes the difficulties that would attend such use of it, yet he believes that most of these may be overcome; and he has ascertained from calculations and experiments that explosives may be made from liquid oxygen and combustibles which will rank amongst the most powerful known to science.

Some of the difficulties referred to might be surmounted in the following manner. Liquid air being produced at the price named, a specially constructed centrifugal machine might separate the oxygen from the nitrogen without much additional cost. The oxygen could be used in making explosive cartridges, which could be packed in a bath of liquid nitrogen. The nitrogen being more volatile than the oxygen, there would be practically no loss of oxygen from the cartridges. The material could be kept in this way for some time, but as it could be made at the mine, or in the mining district, not many hours need intervene between its production and its use. In charging holes, they could first be chilled by a jet of the liquid nitrogen, and further to protect the cartridges against too rapid evaporation of the oxygen, they could be covered with a combustible non-conductor of heat, which would form part of the explosive. The explosive would be so quick in its action that little

* *Trans. Inst. M.E.*, 1900, vol. xix., page 164.

or no tamping would be necessary, and in any case, water or sand-tamping would suffice. To prevent the tamping from being blown out by the evaporating oxygen, a small and very thin copper tube could be inserted into each hole whilst loading, which would serve both as a vent-hole and as a means of firing the charge.

In order to allow for evaporation, 3 pounds of oxygen might be used to 1 pound of carbonaceous matter in producing explosives. At 10d. per gallon the oxygen would cost about 1d. per pound. The carbonaceous matter would not cost more than ½d. per pound. The explosive, therefore, would cost about 1d. per pound. If this cost be doubled to make allowance for incidentals, labour and interest on capital, and add ½d. per pound for loss by evaporation, we should still have a powerful explosive, possessing obvious advantages over dynamite at less than half the cost. X.Y.Z.

USE OF SAFETY-EXPLOSIVES IN GASSY MINES IN FRANCE.

Commission du Grisou: Rapport fait au Nom de la Commission du Grisou sur l'Emploi des Explosifs de Sureté dans les Mines à Grisou. By L. AGUILLON. *Annales des Mines*, 1899, *series* 9, *vol. xvi., pages* 551-573; *Partie Administratif*, 1899, *series* 9, *vol. viii., pages* 667-670.

This report has been made upon the working of the circular of August 1st, 1890* and the special order of the Mining Board of Saint-Etienne as to the advisability of printing upon cartridges the composition of the explosive, more particularly in the case of the Favier explosive.

Use of Explosives.—Three kinds of safety-explosives are used:—Government octonitric cotton (little used), the grisounites or dynamites with nitrate of ammonia, and the Favier grisoutines. The quantities of explosives of all kinds used per ton of coal in three coal-fields are as follows: Gard, 1·76 ounces (50 grammes); Pas-de-Calais, 1·05 ounces (30 grammes); and Saint-Etienne, 0·77 ounce (22 grammes).

The increased cost due to the introduction of safety-explosives is small, the cost of explosives per ton of coal, before 1890, was 0·938d (9·87 centimes), since 1900, 1·011d. (10·63 centimes), showing an increase of cost per ton of 0·073d. or 0·76 centime.

Accident Statistics.—There are two points which should be considered before any explosive can be called relatively safe: (1) the danger when fired of igniting gas, and (2) the danger which it presents in storing and handling.

Statistics shew that there had been no increase in the safety of the miner since 1890, and that the handling and storing of safety-explosives had not resulted in any increase of danger to life.

Restriction of the Employment of Safety-explosives.—By the order of 1890, the Government reserved the right to prohibit the use of any explosive in certain mines or of allowing their use under special conditions, for instance (1) when the pit is empty, and (2) the possible limitation of the charge. The Administration possess the right, and the inspectors of mines have the power, to prohibit the use of any explosive in gassy or badly ventilated mines, but as yet these powers have rarely been exercised.

The charges of explosives used for blasting stone canches in the Nord and Pas-de-Calais coal-fields are: ordinary stone, 8½ to 10 ounces (240 to 300 grammes); hard stone, 28 to 35 ounces (800 to 1,000 grammes); and very hard

* *Report of the French Commission on the Use of Explosives in the Presence of Fire-damp in Mines*, translated by Messrs. W. J. Bird and M. Walton Brown, page 159.

stone, 53 to 70 ounces (1,500 to 2,000 grammes). In stone-drifting, the charges are: fast shots, 28 to 53 ounces (800 to 1,500 grammes); loose shots, 14 to 35 ounces (400 to 1,000 grammes). The heaviest charges are used in the Gard coal-field, and are usually 127 to 134 ounces (3,600 to 3,800 grammes) for holes 13 to 15 feet (4 to 4½ metres) long. It may be added, moreover, that the general tendency in all the districts is to increase the weight of the charge.

Extension of the Powers of Inspectors, the Derogatory Rule.—The inspectors of mines were, by the order of 1890, permitted to modify the regulations in special cases, as for instance at Saint-Etienne, where the rules for stone-work were extended and permitted to be followed in the coal.

Manufacture of Explosives.—Certain explosives are too hygroscopic, necessitating their immediate use, and leading to their being packed in thick paper cartridges, which, when the explosive is fired, are apt to burn: the use of metal cartridge-cases should overcome this difficulty.

Miss-fires.—There are too many miss-fires, especially in the use of explosives for blasting coal; and it is suggested that hints should be taken from the improvements introduced by foreign manufacturers, as for instance by the partial substitution of chlorate of potash for nitrate of ammonia, or as in the German dahmenite, where an improvement was made by the addition of bichromate or permanganate of potash.

Sundry Observations.—The danger from the use of fuses is noted and the use of electricity of low voltage is recommended.

Amended Regulations.—As the result of this report, the Minister of Public Works has issued a circular, modifying clauses 5 and 7 of the circular of August 1st, 1890,* as follows:

5. The stemming of the explosives ordered by Article 2 should be carefully made with plastic matter, so as to avoid blown-out shots; the length should not be less than 8 inches (0·20 metre) for the first 1,543 grains (100 grammes) of charge, with the addition of 2 inches (5 centimetres) for each 1,543 grains (100 grammes) increase in the charge. The maximum charge shall be 35 ounces (1 kilogramme). Detonation shall be made by a fulminating capsule strong enough to insure detonation, even if exploded in the open air.

7. Special prefectoral decrees, which shall be revocable, after the report of inspectors of mines, for particular cases and under conditions which shall be stipulated in the decrees may be issued: (1) For the use of detonating explosives other than those named in Article 2; and (2) Derogations from the obligations of Article 5. C. H. M.

AUTOMATIC SAFETY-DOOR FOR UNDERGROUND EXPLOSIVES MAGAZINES.

Selbstthätiger Abschluss für Unterirdische Sprengmittelmagazine. *By* JAROSLVV JICINSKY. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1900, *vol. xlviii., pages* 345-346, *with* 4 *figures.*

In providing an extra underground magazine to hold 220 pounds (100 kilogrammes) of dynamite in the eighth level at the Theresia shaft of the Witkowitz collieries, the erection of a safety-door on the plan recommended by the French committee on fire-damp and explosives was considered too expensive, and the following arrangement was adopted. The magazine is situated in a short blind gallery, 30 feet (9 metres) long, approached by a branch heading, 9·8 feet (3 metres) long, driven at right angles to the unworkable Thea seam. In the water-level of this latter, the safety-door was erected

* *Report of the French Commission on the Use of Explosives in the Presence of Fire-damp in Mines*, translated by Messrs. W. J. Bird and M. Walton Brown, page 162.

at a distance of 62·3 feet (19 metres) from the magazine, on a concavo-convex dam of 40 inches (1 metre) of cement-and-brickwork recessed into the walls of the gallery and containing a central doorway 4·9 feet (1·5 metres) in diameter. The door was composed of two iron plates, one 0·79 inch (20 millimetres) thick and 67 inches (1·70 metres) across, the other 0·39 inch (10 millimetres) thick and 57 inches (1·45 metres) in diameter, bolted together so as to leave an intermediate space of 2·75 inches (70 millimetres). A ring of felt, 0·39 inch (1 centimetre) thick and 3·9 inches (10 centimetres) wide, was laid round the edge of the larger plate to make the door fit tight into the rebate, 1·18 inches (30 millimetres) deep, in the dam.

Commonly, the door, which opens inward towards the magazine, is kept open about halfway for purposes of ventilation, a stop-block preventing it from swinging back too far; but in the event of an explosion in the magazine it would be blown to by the pressure of the gaseous products of the explosion, a force of 0·1 atmosphere being sufficient for that purpose.

The pressure of gas produced by the explosion of 220 pounds (100 kilogrammes) of dynamite in a chamber of the size projected (47 cubic metres or 1,660 cubic feet) is 20 atmospheres, whilst the door-plate will stand a pressure of 21·7 atmospheres. The total cost of materials and labour amounted to £40 (796 kronen) or rather less than one-third of the cost of a safety-door built on the French plan. C. S.

A NEW METHOD OF SHAFT-SINKING.

A New Method of Shaft Sinking. *By* G. C. McFarlane. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix.*, *page* 411, *with* 4 *figures.*

The writer illustrates a method which he devised for handling the water while sinking through a bed of water-bearing gravel and several strata of water-bearing sandstone, which caused a flow of 200 to 300 gallons per minute. The method, with slight alterations, can be used in sinking through any water-bearing rock. Two holes are drilled to a suitable distance below the water-bearing strata, and a communication made between them at their bottom ends. Holes, 8 and 10 inches in diameter, are suggested as suitable dimensions. The shaft is sunk on one of the bore-holes, and the other hole is in the solid strata outside the circle of the shaft. The water runs from the hole in the shaft into the other hole, whence it can be pumped by a convenient method. By this method, the bottom of the sinking-shaft is always kept dry, and it is possible to fire heavy shots without damaging the pumps. When the shaft is sunk to within a few feet of the coal, the regular mine-pumps can be installed, and the pump-rods and casing withdrawn from the adjacent bore-hole. In sinking a shaft where the bottom would be in hard rock instead of in a coal-seam, the holes should be drilled 20 or 30 feet deeper than the shaft-bottom, and successively larger charges of dynamite exploded in the bottom of both holes until a connection is established between them. X. Y. Z.

SINKING A SHAFT BY THE POETSCH FREEZING METHOD.

Charbonnage de Blaton à Bernissart, Siège d'Harchies: Fonçement par le Procédé Poetsch. *By* J. De Jaer. *Annales des Mines de Belgique*, 1900, *vol. v.*, *pages* 264-267 *and* 467-470.

The Harchies pit is being sunk by the Poetsch freezing method to a depth of 787 feet (240 metres). Freezing was commenced on May 16th, 1899, and the ground was sufficiently frozen to commence sinking on August 1st. A central

bore-hole was employed to ascertain the extent of the freezing, and reached down to the same depth as the freezing tubes. The formation of the wall of ice stopped the flow of water into this bore-hole.

The shaft-lining was formed of rings, 4 feet 10 inches high, cast in four segments and inserted in lengths of 164 feet (50 metres). While the lining was being placed in position in the first length, the sinking was being continued for the second length. The crib at a depth of 164 feet (50 metres) rested on a ledge 6 to 10 feet (2 to 3 metres) high. Above this ledge an excavation was filled with concrete, prepared with water rendered uncongealable by sulphate of soda.

Four leakages occurred in the freezing tubes, causing considerable delay.

The sinking had reached a depth of about 440 feet (133 metres) on April 28th, 1900, and is still in progress. R. W. D.

CEMENT-CONCRETE LINING OF A SHAFT.

(1) *Approfondissement d'un Puits dans le Terrain Houiller et Établissement Simultané d'un Revêtement Monolithe.* *By* JULIEN LINET. *Revue Universelle des Mines*, 1899, *vol. xlviii., pages* 1-16, *with* 3 *plates.*

At Ougrée, an air-shaft has been sunk to a depth of 328 feet (100 metres) from 1,575 feet to 1,903 feet (480 metres to 580 metres). It was known that the strata were irregular, the dip ranging from 50 to 75 degrees, so that a variation of the ordinary method of sinking became necessary. It was proposed to use a closely-fitting lining of channel-iron rings, supported by iron uprights placed 40 inches (1 metre) apart, enclosed with brickwork, but it was finally decided to use cement-concrete alone in the following manner:—

The pit was sunk to full dimensions without any lining, to a depth of 10 or 12 feet. A wooden cylinder, 40 inches (1 metre) high and 9·84 feet (3 metres) in diameter, was supported on battens, and cement-concrete was filled and pressed into the spaces between it and the sides of the shaft, for a width of about 10 inches (250 millimetres); a second cylinder was then placed above the first, and so on, until the bottom of the upper lining was reached, the joint being made by ramming in the last 6 inches of cement-concrete horizontally.

The cement-concrete was made of 6½ parts of broken blast-furnace slag, 11 parts of sandstone wrought from stone-drifts, and 2½ parts of cement (made from blast-furnace slag). The cement-concrete had a resistance to crushing of about 4,300 pounds per square inch (300 kilogrammes per square centimetre), while bricks only average 172 pounds per square inch (12 kilogrammes per square centimetre).

The comparative costs of the two systems were as follows:—

	Brick Lining.		Concrete Lining.	
Diameter of shaft	13·12 feet	4 metres	12·40 feet	3·8 metres
Volume of rock extracted per metre	..	12·57 cubic metres	..	9·62 cubic metres
Volume of rock extracted per foot	136 cubic feet	..	120 cubic feet	..
Cost of sinking per metre	..	100 francs	..	65 francs
do. per foot	£1 4s.	..	17s. 6d.	..
Speed of sinking per day	3·28 feet	1·00 metres	4·52 feet	1·38 metres
Thickness of lining	1·64 ,,	0·50 ,,	0·82 ,,	0·25 ,,
Inside diameter of shaft	9·84 ,,	3·00 ,,	9·34 ,,	3·00 ,,
Volume of lining-material per metre	..	5·5 cubic metres	..	2·55 cubic metres
Volume of lining-material per foot	59 cubic feet	..	27 cubic feet	..
Cost of lining per metre	..	68·75 francs	..	27·67 francs
do. per foot	16s. 8d.	..	6s. 0d.	..
Length of lining inserted per day	6·56 feet	2 metres	13·12 feet	4 metres

M. W. B.

(2) *Charbonnage de Bonne-Espérance: Cuvelage en Béton d'un Nouveau Puits.* By E. FINEUSE. *Annales des Mines de Belgique*, 1900, *vol. v., pages* 485-491, *with* 2 *illustrations.*

The strata to be sunk through were 17·39 feet (5·30 metres) of clay, 15·41 feet (4·70 metres) of sand, and 13·12 feet (4 metres) of gravel. The lower 6½ feet of gravel contained water. In sinking down to the water-bearing gravel, a wooden drum was used, composed of 1¼ inches planks supported by cribs in the inside. The internal diameter of this drum was 18·5 feet (5·65 metres). An iron shoe, in four segments, was then placed inside the drum at the bottom of the pit. This shoe had a width of about 12 inches (30 centimetres), thus reducing the internal diameter to 16·40 feet. Before commencing to build the concrete, steel plates, 0·49 inch (1¼ centimetres) thick, were nailed round the drum and well greased. Against these plates, ¾ inch planks were placed, and the concrete was then built up 11¾ inches thick, resting on the iron shoe to a height of 16·40 feet (5 metres).

The gravel was then removed from below the shoe, and the concrete lining sank down through the water-bearing beds and for a distance of 2 feet (0·60 metre) into the underlying strata. The excavation was carried down for about 6 feet further to a point where a suitable foundation could be formed, and on this foundation a concrete lining was built, reducing the internal diameter of the shaft to 13·94 feet (4·25 metres) and continued to the surface of this diameter.

The operation was commenced on July 26th, 1899, and finished on December 24th, of the same year. R. W. D.

REPAIRING WOODEN TUBBING OF SHAFTS BY INJECTION OF CEMENT.

Note sur la Réfection d'un Cuvelage en Bois au Puits d'Air du Charbonnage d'Abhooz, au Moyen du Procédé Henri Portier. By EMILE WÉRY. *Revue Universelle des Mines*, 1900, *vol. li., pages* 295-300, *with* 1 *plate.*

In Belgium are many old shafts lined with wooden tubbing, from which, in spite of constant repair, there are leakages of large quantities of water, resulting in a double expense for labour and for pumping of water. The winding-shaft at Abhooz colliery was lined with wooden curbs in 1840. In 1895, the quantity of water passing through the lining amounted to 300,000 gallons (1,400 cubic metres) and it was found necessary to reline the shaft with cast-iron tubbing. This operation cost £6,000 (150,000 francs), and occupied six weeks.

The upcast shaft at the same colliery was also in a bad condition, and it was estimated that a sum of £2,000 (50,000 francs) would be required for relining by the ordinary method. It was decided to try Mr. Henri Portier's process of injecting slow-setting cement, diluted with water, behind the shaft-lining. The cement passes into the fissures, closing them, and consolidating the whole structure of the shaft.

To inject the cement, four wooden cisterns were placed at the surface near the pit: they could be kept full of water, and were connected by pipes 1·18 inches (30 millimetres) in diameter, with the points of injection. At these points, valves were fixed into the shaft-lining, and holes were bored into the lining 0·79 inch (20 millimetres) in diameter, passing through the centre of the valve. The water-pipes were connected to those valves by flexible tubing. At the top of the water-pipes, valves were arranged, so that

they could be connected either with the water-cisterns or with a force-pump, or with the atmosphere. The cement was very finely ground, and introduced into the water-cisterns so as to form a milky liquid. The difference of level between the surface and the level of the water in the strata amounting to 52·4 feet (16 metres) provided sufficient pressure to force this liquid behind the wooden-tubbing, when the valves were opened. If any obstruction occurred, it was cleared away by the introduction of a little fresh water by means of the force-pump. Cement was added to the cisterns, so as to keep the water always of the same consistency. The quantity of cement introduced behind the tubbing by this method amounted to 18·1 tons (18,500 kilogrammes), and on the completion of the operation the loss of water was reduced to 330 gallons (1·5 cubic metres) per 24 hours.

The cost was as follows:—

	£	s.	d.	Francs.
Patent right	120	0	0	3,000
Valves, cisterns, pipes, etc.	44	17	7	1,122
Labour	4	17	7	122
Cement	37	0	0	925
Removing the pipes, etc.	5	11	2	139
Totals	£212	6	4	5,308

The saving in pumping-charges amounts to £400 (10,000 francs) per annum. R. W. D.

MOVABLE CRADLES FOR LINING SHAFTS.

Note sur l'Emploi des Plafonds Mobiles pour le Moellonage des Puits en Fonçage. By — DE SERRES. *Comptes-rendus Mensuels des Réunions de la Société de l'Industrie Minérale*, 1899, *pages* 141-143, *with* 1 *plate.*

The new cradle for lining shafts at the Saint-Etienne colliery consists of a movable platform (suspended by pulleys and ropes from rail-ends built into the walling, and projecting 1 foot into the shaft) worked by the men engaged in the lining. It is necessary, for carrying out this method, to have sufficiently strong mooring-points, and pulley-blocks that work smoothly; but this is all that is required. The lining was effected in lengths, or sections, of 98 feet (30 metres), and, when it was built up 12 feet (3 or 4 metres) above the ledge on which it was seated, the four rail-ends, with the flanges uppermost, were built into the masonry at the ends of two diameters crossing one another at right angles. From each projecting end is suspended a chain, 49 feet (15 metres) long, carrying two pulley-blocks, the two ends of the lifting chain being attached to the frame of the upper pulley, forming part of which is a worm-wheel worked by a horizontal gun-metal worm and endless chain. Each of the four pulley-blocks is capable of supporting 2 tons; and the whole load of the platform, with 6 or 8 men and their tools, does not exceed 1·8 tons.

While the platform is being shifted—only once for the 98 feet (30 metres) length or section—the men wear safety-belts; and while they are at work the platform is made fast by four bolts shot into holes left in the masonry, the falls not running down, whatever weight be put upon them, owing to the slow pitch of the screw. One man is sufficient to work the pulley-blocks, which are connected to the platform by chains, 7 feet (from 2 to 2½ metres) long,

so as to prevent the lower-pulley blocks from being choked with mortar; and, after each length of masonry is built, the chain and pulley-blocks are thoroughly cleaned on the surface.

The advantages of this method were clearly shown by a comparison of the progress made with the movable platform and that made with the fixed platforms by which the first length, or section, was lined. Whereas in the latter case, the mean speed of lining was only 6½ feet (2 metres) and the maximum 10 feet (3 metres) daily; in the former the mean advance was 10 feet (3 metres), and the maximum 13 feet (4 metres) daily, five days being thus gained in each length for the lining alone. At least as much time was saved in erecting the air-pipes and ladders, making a total saving of 2 months in sinking to a depth of 590 feet (180 metres) while the money saving was also considerable. The total cost of the four sets of pulley-blocks, with lifting and working chains, was £41 12s. (1,040 francs); and the sum of 14s. 6d. per foot (60 francs per metre) was saved in labour during the sinking. J. W. P.

DRAINAGE OF THE LAMARTINE MINE, COLORADO.

The Lamartine Mine. *By* PROF. ARTHUR LAKES. *Mines and Minerals*, 1900, *vol. xx., pages* 385-387, *with* 5 *illustrations.*

The Lamartine vein, Idaho Springs, Colorado, was discovered in 1867, but no workings of importance were prosecuted until some 20 years later. After about 10 years, the present main shaft was sunk to a depth of 906 feet, and ten levels were opened. In 1893, the workings encountered the Crown vein, carrying high values in gold. The Crown vein crosses the Lamartine vein, and on the junction rich and large ore-bodies were opened, extending up and down in junction vertically for 400 feet and laterally east and west for 250 to 700 feet on both veins. At the time of finding the Crown vein, large volumes of water were met with, and the fuel expense of pumping rose to £20 (100 dollars) per day. It came to be a problem whether to abandon the mine, or drain it by a tunnel over 1 mile in length, and the latter course was decided on. The mine is situated on the summit of French mountain, and it was decided to drive a tunnel from the surface at the back of the hill and on the Lamartine vein, which would tap the lowest level of the mine. This tunnel was begun on October 16th, 1894, from the surface. Meantime, water had been removed from the lower levels of the mine, and on November 5th, 1894, the work of driving from the lower levels eastward from the shaft to connect with the tunnel began.

The tunnel going east from the workings was driven on a down grade of 1 per 100; and therefore necessitated the pumping of vast quantities of water back to the main pumping station, by auxiliary machinery. On April 5th, 1895, a sudden flow of water was encountered, and caused a suspension of work for 21 days, during which a second large compound pump was installed in the pumping-station, whilst additional auxiliary pumps, mounted on trolley-cars, commenced work on the recovery of the heading. Five times after that, prior to the completion of the tunnel, the men were driven out of the heading by sudden flows of water from pockets.

On March 29th, 1896, both headings were brought together, completing actual drivings of 4,611 feet in 17 months' time, 1,531 feet being driven down on the incline at a cost of all expense outside of pumps of £3 16s. (18¼ dollars) per foot; and 2,080 feet driven from the surface cost at the rate of £3 10s. (16¾ dollars) per foot; this covered every item of cost, including that of boiler

and air-compressor plant at the mouth of the tunnel. The problem of connecting the tunnel-ends was a delicate one, as the surveyor had but one working shaft down which he could extend plumb-lines. The lines were spaced 4 feet apart, when hanging in the shaft for a depth of over 900 feet. The difficulty of vibration was overcome by using plumb-bobs each of 25 pounds weight, suspended in a tub of heavy glucose syrup. The course of the tunnel was circuitous, following the sinuous course of the vein for 2,600 feet and the remainder through barren country rock.

Since the completion of the tunnel to the main shaft, it has been extended westward, until its total length now exceeds 6,700 feet. The size of the tunnel is 8 feet by 8 feet. The water flows in a ditch by the side of the track, and in drainage-expenses alone, the tunnel has already saved over £41,666 (200,000 dollars). But the tunnel is also used to run the waste-rock and rubbish from the mine to the outlet of the tunnel, where the dump is from 160 to 200 feet high, and covers 2 acres of ground. Very little timber is used, the walls being firm and strong, and one thing of notice in this long tunnel is the row of main chutes descending from the working above and discharging rubbish into the cars. X. Y. Z.

PACKING OF WORKED SEAMS IN BAVARIA.*

Erfahrungen über Abbaumethoden mit Bergversatz. By HEINRICH MÜLLER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1900, *vol. xlviii., pages* 347-351, *with* 4 *figures.*

With the progressive deepening of the workings at the Hausham colliery, Upper Bavaria, the rock-pressure attained such dimensions as to crush the coal-pillars, and become a source of great expense in repairs and of danger to the miners; consequently the pillar and subsidence method with partial packing, hitherto followed, had to be abandoned in favour of longwall work. The plan finally adopted was to drive headings both ways from the haulage-incline, through the thin (20 to 24 inches) upper seam and the thicker (44 to 46 inches) lower seam. From these headings a number of intermediate cross-drivages were cut in the lower seam to enable the face to be attacked at a larger number of points simultaneously, and thus clear out the same superficial area as in the thinner upper seam. In order to prevent the toughening noticeable in the latter when the thicker seam is worked first, the last-named is always left one step in the rear. The haulage-incline of each working district is laid in the upper seam, and is fitted with a winch for raising the packing; a safety-pillar about 32 feet thick is left on either side above the drainage-gallery, and the coal is taken out from the lower level first, so that the waste-rock collected in driving the incline can be lowered to serve as packing. The working length of each section is about 1,640 feet (500 metres) with a superficial height of 328 feet (100 metres), so that after deducting 33 feet (10 metres) for the safety-pillar above the drainage-gallery, six lifts, each of 49 feet (15 metres) in height, can be set out one above another. The coal got from the thicker seam is removed through the intermediate cross-drivages into the headings in the thinner seam, and thence through a winze. When all the coal is out, these cross-drivages are abandoned.

This method ensures uniform production and obviates the 19 to 20 per cent. waste occasioned by the pillar system, considerations more than outweighing the greater cost of working. C. S.

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* *Trans. Inst. M.E.*, vol. xix., page 505.

FLUSHING OF CULM IN ANTHRACITE COAL-MINES.

Flushing of Culm in Anthracite Coal-mines. By WILLIAM GRIFFITH. *The Journal of the Franklin Institute*, 1900, *vol. cxlix., pages* 271-282, *with illustrations in the text.*

Recently, the "flushing method" has been adopted for disposing of the waste from anthracite-mines. By this process the culm and waste material is carried back to the mine, with water, and allowed to fill part of the abandoned portions of the underground workings.

The process is a very simple one. The culm, as it accumulates in the breaker, is carried through a system of "telegraphs" or conveyors to a hopper—usually an oil-barrel. A stream of water is also conducted into the same hopper by means of a 3 inches pipe, and the culm is carried by the water through a pipe usually 4 inches in diameter, passing out of the bottom of the hopper. This pipe, passed down into the mines through the shaft, or by means of a bore-hole, is conducted along the gangways and up the chambers through the cross-cuts to the point where it is desired to deposit the culm. The pipe used is an ordinary black wrought-iron pipe. The joints are ordinary screw-joints; or more commonly a piece of 4½ inches pipe, about 8 inches long, is split on one side and placed round the pipe, being held together by two clamps. This form of joint is very simple and easy to apply. It leaks for a short time after being put on, but the crevices are soon stopped by the culm, and the joint becomes tight. This pipe may be carried from the foot of the shaft, either up or down the pitch. Of course, if it is carried up the pitch, more water is required to deliver the same amount of culm than is the case where the pipe is carried down the pitch or on the level. The culm flows freely through these pipes for long distances, and may be deposited at almost any point in an ordinary anthracite-mine. The water is usually turned on about 15 minutes before the work starts at the breaker, and is allowed to run about 15 minutes after work stops in the evening, in order thoroughly to clean the pipe. Occasionally, stoppages occur when the pipe becomes filled with culm from one end to the other, and this of course requires considerable time and trouble to get clear again. It is usually accomplished by breaking a joint near the foot of the shaft, and allowing the pressure of the water to force the culm out of a section, 100 or 200 feet in length. Connection is then made and again broken several lengths further on, and the water used to clean the pipe again. This process is continued, until the pipe is all cleared.

The culm issuing from the pipe is discharged into the highest point of the chamber or portion of the mine desired to be flushed, and stoppings are placed at the outlets of the chambers, near the gangways. The culm, as it is deposited from the end of the pipe, takes a very flat slope, and is carried a long distance by the water, which ultimately sinks away and filters through the deposited culm to the lower portion of the mine, whence it is pumped to the surface by the mine-pumps. The stoppings are often simply board partitions placed across the end of the chamber and fitted closely, or sometimes dry walls of slate or mine-rubbish are used, a dyke of culm being piled behind the wall, through which the water may filter.

When the chamber is filled to the roof, the pipe is withdrawn and culm allowed to run into the next chamber, and so the process continues until the desired area is completely filled with culm.

Among the advantages claimed in favour of the flushing process may be mentioned the help that may be afforded to the pillars by flushing culm at the time of a squeeze in a coal-mine. It is also said to be a preventive of mine-

fires, as a mixture of culm with water might readily be used for the purpose of drowning a fire, since by placing the proper stoppings around the fire, as is usually done, for excluding the air, water-and-culm could be flushed in through boreholes from the surface until the space was completely filled with wet culm. This method would effectually exclude the air, and in all probability stop the fire, particularly if water were kept running in the bore-hole, so that it could seep through the culm in order to keep it wet. Another advantage is that an additional quantity of coal may be mined by first flushing the old workings with culm, and then extracting the pillars. This may be safely done, but the percentage of extra coal recovered depends, of course, upon the conditions which obtain at each colliery; perhaps, however, 20 or more per cent. may be saved, provided that the mine is worked and portions flushed with the view of recovering it.

This question of flushing of culm into mines may eventually, the author considers, be expanded to the larger question as to whether or not it may be advantageous, when facilities warrant, to flush sand, loam and other material from the surface into the mines for the same purpose. M. W. B.

MACHINE-HAULAGE IN THE COLLIERIES OF UPPER SILESIA.

Die Maschinellen Streckenförderungen auf den Oberschlesischen Steinkohlengruben. By DR. HEIMANN. *Glückauf*, 1900, *vol. xxxvi., pages* 449-456; *and Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, 1900, *vol. xlviii., pages* 18-51, *with* 13 *figures.*

In Upper Silesia, (*A*) chain-haulage is employed in six pits; (*B*) rope-haulage: (*a*) using knots at seven pits; with double knots at three pits; with single knots at four pits; (*b*) using smooth ropes at ten pits; with forks at three pits; (*C*) with chain-couplings at seven pits; (*D*) locomotive haulage at three pits: electric locomotives at two pits; and a locomotive worked with benzine at one pit. Table I. shows the results obtained.

In comparing chain- and rope-haulages, the following points may be noted as in favour of rope-haulage. (1) The chain is considerably heavier than the rope, 1 metre weighing 17·63 pounds (8 kilogrammes); whilst 1 metre of corresponding rope weighs about 3·96 pounds (1·8 kilogrammes). The use of the latter, therefore, constitutes an important economy in dead weight. If it is assumed that the tubs follow at distances of 66 feet (20 metres) apart, each tub will carry a weight of 353 pounds (160 kilogrammes) of chain. As the distance between the tubs cannot always be kept uniform, but sometimes increases to 130 or 200 feet (40 to 60 metres), this weight is correspondingly increased, so that the tubs themselves are liable to suffer considerable damage, especially as regards bending of the axles and crushing of the front plates. (2) It is much more difficult to turn a curve with a chain than with a rope. (3) With a chain, a definite minimum output must be fixed. If the amount of coals to be carried be small, empty tubs must be inserted, to prevent the chain from dragging on the ground; because if the chain is allowed to drag, it not only becomes worn, but very much additional work is thrown upon the hauling-engine. If, on the other hand, the quantity to be transported be very great, the distance between the tubs has to be decreased to such a point that the weight of the chain is no longer sufficient to drag them. In this case, therefore, a very heavy chain must be employed, or else forks must be used. In this latter case, the special advantage of the chain, namely, the absence of

any form of coupling between the chain and the tub, is lost. In the case of ropes, the objection that there must be a minimum amount of mineral transported does not appear, seeing that endless-rope haulage will pay even with a daily transport of 250 tons, and there is also much less danger of a rope dragging on the ground than in the case of the chain. The maximum limit is very much higher than in the former case, because the tubs can be put as close together as required when a rope is used, and by using the newer methods of chain-couplings, or clutches, as many as 4 tubs at a time can be attached. If there are several points at which tubs have to enter and leave the system, this is very much more easily effected in the case of ropes than in the case of chains.

TABLE I.

Nos.	Name of Pit and District.	Length of Haulage.	Number of Curves.	Number of Loading Stations.	Annual Efficiency.		Cost per Ton.	
							Kilom.	Mile.
	A.—CHAIN-HAULAGE.							
		Metres.	Feet.		Ton Kilometres	Ton Miles.	Pfennig	Pence.
1	Hugo und Zwang	400	1,312	—	1	87,000	53,193	10·40	1·97
2	Mathilde, Westfeld ..	1,430	4,691	*	3	124,860	76,341	10·80	2·05
3	Deutschland	800	2,624	—	1	182,400	111,522	4·08	0·77
4	Hohenzollern	1,850	6,069	1	—	271,828	166,200	4·30	0·82
5	König, Bahnschacht ..	1,370	4,494	—	3	510,616	312,198	3·98	0·76
6	Concordia	1,160	3,805	3	4	512,000	317,935	4·90	0·93
7	Mathilde, Ostfeld	1,440	4,724	2	3	523,107	319,835	5·50	1·04
	B.—ROPE-HAULAGE WITH CLIPS.							
1	Brade	850	2,788	—	2	62,700	38,336	7·50	1·42
2	Deutschland	560	1,837	—	2	120,000	73,370	6·80	1·29
3	Beatensglück	1,122	3,681	8	7	135,000	82,541	9·50	1·80
4	Consolidated Florentine	1,150	3,773	1	1	136,760	83,917	5·90	1·12
5	Hedwigswunsch	1,850	6,069	7	—	193,578	118,356	14·70	2·77
6	Redensblickschacht II.	1,530	5,019	3	3	218,325	133,486	7·50	1·42
7	Brandenburg	1,605	5,265	—	2	326,000	199,321	4·80	0·91
8	Ferdinand	1,460	4,790	6	2	493,584	301,784	5·70	1·04
9	Königin Luise, Ostfeld	1,680	5,511	1	3	596,656	364,984	5·30	1·00
10	Do., Westfeld	2,200	7,218	2	2	1,275,990	780,158	1·96	0·37
	C.—ROPE-HAULAGE WITH COUPLING-CHAINS.							
1	Myslowitz	1,000	3,280	—	2	252,972	154,671	7·05	1·33
2	Cleophas	650	2,132	—	2	273,600	167,283	5·10	0·96
3	Königs, Südfeld	1,532	5,026	11	4	308,328	188,516	9·90	1·88
4	Königs, Ostfeld	1,100 700	3,608 2,296	—	—	417,636	255,348	6·60	1·23
5	Consolidated Giesche, Kronprinzschacht ..	1,820 1,000 2,000	5,971 3,280 6,561	—	—	490,800	300,082	7·70	1·46
6	Laurahütte, Richter Schächte	550 1,100 1,400	1,804 3,608 4,593	—	—	519,030	317,324	6·70	1·27
7	Gräfin Laura, Bahnschacht	—	—	5	—	894,988	547,208	4·20	7·90
	D.—LOCOMOTIVE-HAULAGE.							
1	Laurahütte, Knoffschacht	450	1,476	—	—	44,550	27,238	7·70	1·46
2	Lythandra	1,250	4,101	Num'rous	—	121,107	74,046	8·60	1·62
3	Paulus-Hohenzollern ..	—	—	—	—	199,299	121,854	7·90	1·50

* Almost straight.

H. L.

ENDLESS-ROPE HAULAGE.

Slope No. 6, *Pratt City, Alabama: An Example of Endless-rope Haulage, the Longest Haulage in the South.* By NEILL HUTCHINGS. *Mines and Minerals,* 1900, *vol. xx., pages* 251-252, *with illustrations in the text.*

At Pratt City, Alabama, where are located the extensive collieries of the Tennessee Coal, Iron and Railroad Company, it was a puzzling question to the company's engineers whether the coal could be mined cheapest through an expensively steep rock-slope, or by means of a haulage of unusual length

through the No. 6 slope. The introduction of the latter meant an outlay of about £6,000 (30,000 dollars), not including the cost of the rope and cars; an endless-rope haulage of 2½ miles round curves of 24 degrees and 39½ degrees; pinion-wheels able to stand the strain of hundreds of loaded cars on a rope of this length (this has since been found to be the hardest matter to overcome), and minor details of almost equal difficulty. The work was commenced in 1898. From the slope-mouth to the bull-wheel, the original distance was 11,765 feet, but is now several hundred feet longer. The principal difficulty of making the endless-rope haul cars round the curves above-named was solved, by building the track in such a manner that for the entire distance around the curves it was itself curved. The tendency of the rope to run in a straight line on the curves was thus overcome, the strain coming on the lower part of the cars, holding them firmly on the track until the straight stretches are reached. The haulage-system is the overhead; the cars are attached to the rope by goose-necks, and the speed is 2 miles an hour. At the necessary points, the track is graded, so that the cars release themselves from the rope, or attach themselves to it by the action of gravity. The grade of the slope is not unusual, portions being level, and the total difference of level between the slope-mouth and the deepest point, 3 miles distant, is 336 feet. About 135 loaded cars and the same number of empty cars are coustantly on the rope; the output is 600 tons per day, which will soon be largely augmented. Apart from frequent breakages of the teeth of the pinion-wheels, the operations are attended with great success. X. Y. Z.

AN ELECTRIC HAULAGE-PLANT.

Mine No. 15, *Rich Hill, Missouri.* *By* CHARLES EVANS. *Mines and Minerals,* 1900, *vol. xx., pages* 412-413.

Mine No. 15, owned and operated by the Rich Hill Coal and Mining Company, is located 2 miles south of Rich Hill, Bates County, Missouri.

It is entered by a vertical shaft, and the seam of coal worked lies 106 feet below the surface. The mine has produced as much as 1,500 tons in a day, and for a long time averaged 1,250 tons per day. Latterly, the output decreased to 800 tons, due largely to the long haul. This state of affairs suggested electric haulage, and at present the main entry on the south side is worked by that system. The cost of the change has been considerable, the electric plant grading 4,600 feet, of which 1,000 feet was a cut averaging 6 feet in depth in order to secure a proper grade. The motor runs from the shaft to the present face of the southern entry, a distance of 4,600 feet, and makes the round trip of 9,200 feet with 20 cars both ways, in less than 7 minutes. This by no means represents the full capacity of the motor, and the results are so satisfactory that a motor has been ordered for the north side also. The output of the mine quickly rose to 1,100 tons, and will probably reach a daily average of 1,400 tons.

The power-house for the new plant adjoins the old engine-house, and the wires leading therefrom to the mine are provided with resistance-coils and lightning-arresters. The ground-wire in the mine is carried on the left side of the track, and connected with the bond-wires on the track at every third rail on each side of the track. The live-wire is connected to the trolley-wire in the shaft-bottom. The trolley-wire sets 7 inches to the side, and at an elevation of 5 feet from the top of the rail. The electric plant consists of an

automatic high-speed 150 horsepower engine, with two cylinders 14 inches in diameter by 18 inches stroke, driving, with a 16 inches perforated belt, a Westinghouse dynamo, 275 volts, 364 ampères; Weston ammeter; Weston voltmeter; Westinghouse rheostat, 100 kilowatt, 275 volts; magnetic blow-out; circuit-breaker, and a Jeffrey improved motor. X. Y. Z.

ACCIDENTS IN PASSES OR CHUTES IN BELGIUM.

Les Accidents survenus dans les Cheminées d'Exploitation, pendant les Années 1884 *à* 1898, *inclusivement. By* VICTOR WATTEYNE *and* LUCIEN DENOËL. *Annales des Mines de Belgique*, 1899, *vol. iv., pages* 55-95 *and* 281-344.

These accidents are comparatively few in number; and the authors have gone back to 1884, the year in which the last general mining regulations were issued, so as to include a larger number of accidents of this class in their report. During this period of 15 years, 62 accidents occurred in passes, causing 51 fatalities and 13 cases of serious injury. These accidents are grouped according to their causes or the circumstances under which they occurred; and they are treated under the following heads:—(1) Clearing obstructed passes; (2) falls of rock or goaf; (3) falls down the passes; and (4) miscellaneous.

(1) *Clearing obstructed Passes.*—Almost all the accidents of this class, 27 out of 31, happened while the pass was being cleared from below, and only 2 while it was being cleared from above, and 1 through a dynamite-cartridge. These accidents are nearly always fatal, death being generally caused by suffocation. Three of the accidents due to clearing from below entailed the death of lads who happened to be near; and in all the other cases those who effected the clearing were killed. Of the remaining 24 accidents, (*a*) 20 were due to a sudden fall of the obstruction while the workman mounted the pass or stood underneath it, or again was actually proceeding to the work of clearing; (*b*) 1 accident was attributed to suffocation through a too long stay in an atmosphere rendered irrespirable by a large quantity of coal-dust; (*c*) 1 was caused by the formation of a fresh obstruction below the workman; (*d*) 1 arose from the fall of a man as he was mounting the pass to clear it; and (*e*) 1 was due to a fall of roof.

Compared with the number of men engaged in clearing passes, the number of accidents is considerable; and the risk run by those so engaged is greater than that of miners generally. The methods employed for clearing are of two kinds: one consisting in the endeavour to remove an obstruction from the outside, without entering the pass, while in the other the man enters the pass. Among the methods of the first kind is that of pulling chains or knotted ropes previously hung in the passes, a practice that sometimes effects the desired result; and another method, which would appear to be more efficacious, consists in prodding the obstruction with long tools from below. In a third method, both safe and effective, applicable to passes divided longitudinally, one compartment being left free, the man gains the obstruction by the free compartment, takes down part of the brattice, and then the obstruction can be readily cleared. Lastly, even if the pass be not double, it may be reached through the goaf from a neighbouring pass, a communication being made to the obstruction, which can be cleared in the manner just mentioned; but this method is evidently slow, and unsuitable if the strata are insecure or the distance considerable.

In the second category, a distinction must be drawn between two different

methods: one of which consists in descending into the pass and the other in ascending into it from below. In the former case, the man, fastened by ropes to the timbers at the top of the pass, lowers himself into it; he first tries to clear the obstruction by tools, but, failing in this, he fills into skips all the coal, which is drawn up by another man to the upper road. Although slow and not free from danger, this method is far more certain than that of entering the pass from below. When the obstruction is reached, the man builds under it a small platform; and then, working away at the obstruction with tools, he causes the coal to fall, after which he proceeds in one of the two following manners. He either weakens, by saw-cuts or otherwise, the timbers of which the platform is constructed, ties a rope to them and, after descending into the lower road, pulls smartly on to the rope so as to remove the platform; or, remaining in the pass, he makes an opening in the platform, through which he sends down all the coal that has stopped the pass. In other cases, the workman directly removes the obstruction, protecting himself as well as possible with rice-wood (*fagot de fascines*), bringing down the coal at his side and rising in the pass as he forms a passage, often making his exit at the top after having traversed the pass from end to end.

(*a*) When the pass is cleared by moving chains or knotted ropes, if the workman remains underneath the pass he is liable to be overwhelmed by the falling coal; and, if he performs this operation from the top, he may himself fall into the pass. Accidents may be avoided, however, by arranging the chains or ropes so that they can be worked by a man holding on to the side of the pass. With the same precautions, working at the obstruction by long tools may be effected safely either from the top or from the bottom; but in the latter case, if the obstruction be so high that the man cannot avoid placing himself in the centre line of the pass, it is advisable to open the hopper only so much as may be necessary for working the tools, and also to strengthen it by props so as to prevent it from yielding to the shock of falling coal, etc., when the clearing is effected. These two methods, easily employed and free from danger, are to be recommended.

Working at the obstruction by a lateral passage did not cause a single accident during the long period under notice; but the possibility may be feared of a sudden irruption of coal through the opening made in the brattice. If, however, the obstruction be exactly located and the opening be made carefully, such cause of danger may be easily avoided. This method of proceeding may be regarded therefore as irreproachable from a safety standpoint, while it is also effective; but a double pass may be considered to entail too great expense, especially with insecure rocks. On the other hand, the existence of such spaces in the goaf may cause a loss of the air-current; but this disadvantage may be sufficiently avoided by closing the passes at both ends, or at any rate at the bottom end. It is also possible that fire-damp may accumulate in these spaces; but such accumulations, less dangerous than is generally supposed, will not occur if care be taken to avoid closing the upper end. Moreover, it is desirable to provide a sufficient volume of air for leakages through the goaf.

(*b*) Entrance into the pass caused nearly all the accidents during the period of 15 years. When a man descends into the pass, the great danger consists in a subsidence of the obstruction; and, in order to guard against it, he should attach himself by a rope and safety-belt to a strong prop, he should avoid stamping upon the coal, and he should stand on a plank, or on a few timbers forming a rough platform, and try to cause a fall of the coal by a suitable tool. If the pass be cleared from the top, there is the chance of accident

through coal falling out of the skips, or of the skips falling, or of the roof giving way, etc.; but the first source of danger, which is not greatly to be feared, may be avoided with a few precautions.

Entering the pass from below causes a large number of accidents, as the workman is exposed to many dangers from which he cannot be wholly secured. For instance, the coal falling upon him from above, and the platform on which he stands may yield to the falling coal. The stationing of a man at the bottom of the pass and the removal of the hopper, are inadequate precautions; and the formation of the passes at an inclination of 30 to 35 degrees, while diminishing the risk, does not entirely suppress it.

The following precautions are recommended:—Passes should be placed in safe strata, with sufficient slope and without sudden variations or changes of direction. Passes should be securely timbered; the goaf should be secured by pack-walls and a strong lining made of boards, rather than thin flexible timbers; and, if the floor be not sufficiently smooth, it should be covered with boards or iron plates to favour sliding. Passes should not be made at too low an angle; they should be divided into suitable lengths, accessible by supplementary roads; and should not be placed in a straight line, but so that each one can be entirely shut off from the others. Passes should be divided longitudinally by a brattice, so that one compartment may always be accessible to the workmen. Further, the passes should be frequently inspected and repaired, a frequent cause of obstruction due to breakage or displacement of timbers being thus removed; care should be taken that large pieces are not sent down, as they might cause obstruction or damage the lining; and all timbers, rice-wood, etc., that may fall into the passes should be at once withdrawn.

In the event of obstruction, the passes should be cleared by chains or knotted ropes placed in the passes, or by means of boring-rods; and, within double passes or sheet-iron passes, a few blows on the brattice will often dislodge the obstruction. The extreme measure of taking the coal out by the top, or making a passage at the level of an obstruction, should be resorted to only in rare instances.

(2) *Falls of Rock or Goaf.*—Of the 10 accidents recorded under this head, 2 were due to falls of the enclosing rock, and the 7 others to falling-in of the goaf; and, except in two of them, the falls occurred while the passes were being packed or coal was being sent down them, the immediate cause appearing to have been the shock of stones or large pieces of coal against the timbering. It is recommended that passes be built with the greatest care, and timbered carefully and regularly. The passes should always be filled as full as possible; great care should be taken not to throw down them too large pieces that would knock against the sides and remove the timber-lining; and a grating should be placed at the mouth of each pass.

(3) *Falls down Passes.*—It is recommended that (*a*) the mouth of a pass should be protected by a strong movable cover; (*b*) when a large obstruction is to be cleared, two platforms should be built, as is customary in shafts; (*c*) in passes used for travelling with slippery floor, and without transverse timbers, ladders or ropes should be provided; and (*d*) the mouth of any pass temporarily disused, or used for ventilation and travelling, should be so situated as to prevent men from falling into it who have to pass along the roads.

(4) *Miscellaneous.*—The number of accidents in passes may be diminished; but the work of clearing is always dangerous, suffocation being the cause of many fatalities. J. W. P.

COMPOUND WINDING-ENGINES.

Ueber Compound-Fördermaschinen, deren Betriebs- und Dampfconsumverhältnisse. *By* JULIUS DIVIS. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 550-553, 568-570, 581-584, 594-596 *and* 605-607.

The experiments were carried out by the author on a converted compound winding-engine at the Rudolf colliery, Pribram, and a similar but unconverted (non-compound) double-cylinder winding-engine at the Segengottes colliery. The former engine was designed to raise a nett load of 1,650 pounds (750 kilogrammes) a height of 1,476 feet (450 metres), the tubs weighing 550 pounds (250 kilogrammes), the cage 2,420 pounds (1,100 kilogrammes) and the rope 1,760 pounds (800 kilogrammes); and its dimensions were: diameter of the high-pressure cylinder 11·02 inches (280 millimetres), of the low-pressure cylinder 17·71 inches (450 millimetres); stroke 25·59 inches (650 millimetres). The other winding-engine had the same stroke, and two cylinders of the same dimensions as the high-pressure cylinder. For the compound-engine, the author devised a special valve to be held open by the engineman in starting, with a view to prevent waste of steam through carelessness. Both engines were non-condensing, and worked at an admission-pressure of 3 to 3·8 atmospheres.

TABLE I. – EXPERIMENTS ON WINDING-ENGINES.

No. of Experiment.	Non-compound.		Compound.				
	1	2	3	4	5	6	7
Fuel consumed, pounds	1,100	1,474	1,408	1,045	1,045	1,375	1,320
,, ,, kilogrammes	500	670	6·0	475	475	625	600
Feed-water, nett, pounds	5,044	6,030	6,237	5,900	6,208	7,719	5,682
,, ,, kilogrammes	2,293	2,741	2,835	2,682	2,822	3,509	2,583
Height of lift, feet	701·6	901·7	1,102·4	1,102·4	1,102·4	1,102·4	1,102·4
,, ,, metres	213·8	274·8	336	336	336	336	336
Nett load, average, pounds	1,293·8	1,264·5	1,318·0	1,523·2	1,402·7	1,360·7	1,297·5
,, ,, kilogrammes	588·1	574·8	594·1	692·4	637·6	618·5	589·8
Average length of stoppages, minutes	2·11	1·79	1·60	1·72	1·51	1·90	1·71
Output in brake horsepower per hour	44·29	55·00	68·00	70·67	67·45	62·35	59·45
,, ,, brake horsepower	16·90	20·37	22·29	22·50	23·58	22·67	22·18
Steam consumed per brake horsepower per hour, pounds	112·8	108·7	91·7	77·5	92·05	123·8	95·6
,, ,, ,, ,, ,, ,, kilogrammes	51·77	49·91	41·69	35·24	41·84	56·27	43·45
,, ,, ,, percentage ratio	103·72	100·00	83·53	70·60	83·83	112·76	87·05

Table I. embodies a synopsis of the results obtained. The influence of an increased height of lift on the consumption of steam is shown in Nos. 1 and 2 experiments, and the saving effected by compounding may be calculated, from Nos. 2 and 3 experiments, as about 12¾ per cent. for equal heights. The advantage of winding heavy loads for compound engines is seen from Nos. 3 and 4 experiments: the increase of the load by 205 pounds reducing the steam-consumption by 14·2 pounds per horsepower per hour. No. 5 experiment records the result of regulating the admission of steam by the throttle-valve alone, and shows that the compound winding-engine wastes less (3 to 5 per cent.) than the ordinary engine (15 per cent.) through carelessness in driving. In No. 6 experiment, the compound-engine was run as a non-compound, the waste bringing down its efficiency to 12½ per cent. below that of the double-cylinder engine (No. 2 experiment). This illustrates the advantage of a special starting-valve such as the one already mentioned.

On disconnecting the steam-jackets on the cylinders, the results given in No. 7 experiment were obtained, namely, a loss of 3¼ per cent. of steam. A large quantity of water was condensed in the cylinders during this experiment,

and the taps had to be left open throughout, to prevent damage from concussion.

In further tests with a load of 1,390 pounds (632 kilogrammes) from a depth of 1,351 feet (412 metres), the compound-engine exhibited a saving of 10 per cent. in steam-consumption; and taking the results generally the economy of steam in favour of the compound winding-engine was calculated at an average of 12 per cent. C. S.

POWER FROM THE DESCENT OF GOB-MATERIAL.

Descenderie du Puits de la Pompe. *By* — BERNE. *Comptes-rendus Mensuels des Réunions de la Société de l'Industrie Minérale*, 1899, *pages* 270-277, *with* 1 *plate.*

The first installation for compressing air, by the descent of gob-material, comprised two-decked cages taking a tub on each deck, two empty tubs being brought up at every lift. The round steel-wire rope weighed rather more than 14 pounds per yard (7·1 kilogrammes per metre); and the balance-chains each 1,010 feet (308 metres) long, weighed 36 pounds per yard (18 kilogrammes per metre). At bank, the rope passed over three pulleys, 16 feet (5 metres) in diameter, arranged in the same vertical plane, and so that the centre line of one of the cages formed a tangent to the rim of two of them. The shaft of the third pulley, which also served for braking, was coupled to the double crank-shaft driving the pistons of two air-compressing cylinders. On starting, the motive effort was 2·8 tons; and on arrival it was ½ ton. The compressing cylinders, which had a diameter of 17·71 inches (45 centimetres) and a stroke of 39·37 inches (1 metre), were designed to fulfil the condition of (1) not interfering with movement of the cage at landings, while permitting of the attainment of a sufficient speed, and (2) preventing the speed from becoming excessive, especially if the weight of a tub-load should exceed the mean. These conditions were realized, by means of (1) a retaining valve which prevented a return of air from the receivers to the compressing cylinders, and (2) a centrifugal governor acting upon (*a*) a blow-off valve for putting the cylinders in communication with the atmosphere, and (*b*) two valves, between this last-named valve and the cylinders, that prevented compressed air from passing into the cylinders at the highest position of the governor, free communication between them being permitted in all its other positions. The excess of motive power over the resistance was 3,037,929 foot-pounds (420,000 kilogrammetres) which left a margin of 1,573 pounds (715 kilogrammes) for the passive resistance at the rim of the brake-pulley; but careful experiments showed that such resistance did not exceed 705 pounds (320 kilogrammes), so that it became necessary to add an hydraulic regulator.

In the modified plant, the motive energy was greatly increased by not lifting the empty tubs, and the following was to be the normal duty:—Start from the surface with 4 full tubs, take in 2 tubs at the intermediate landing, and again 2 more at the bottom landing. Two cylinders, 30 inches (75 centimetres) in diameter, were added; and, for preventing slip of the rope, a turn was taken round each pulley. A second hydraulic regulator was added, so that 4 full tubs could be lowered in the event of a break-down of the air-compressor. With the new arrangement, 2 or 3 full tubs can be lowered as may be required, without intermission in the production of compressed air: but when 4 full tubs are lowered the motive effort is 4·976 tons, which becomes reduced to 3·715 tons on arrival at the intermediate landing, 1·615 tons on leaving it, and 1·324 tons on arrival at the bottom-landing.

With 3 full tubs, the volume of air compressed to 79 pounds per square inch (5·5 kilogrammes per square centimetre) was 250 cubic feet (7·1 cubic metres), corresponding to an air-volume of 1,377 cubic feet (39 cubic metres) at atmospheric pressure; and the power indicated in the three cylinders was 7,692,256 foot-pounds (1,063,474 kilogrammetres). With 4 full tubs, the power indicated in the four cylinders is 12,157,414 foot-pounds (1,680,794 kilogrammetres) and the volume of compressed air was 396 cubic feet (11·2 cubic metres). When 600 full tubs are lowered daily, the 150 lifts compress 59,331 cubic feet (1,680 cubic metres) of air to the above-named pressure, the distance between the surface and the intermediate landing only being taken into consideration; and for effecting this work by steam a 100 horsepower-engine working 10 hours a day would be required. J. W. P.

FAILURE OF A MUESELER SAFETY-LAMP.

Note sur une Lampe Mueseler ayant produit une Flambée de Grisou. *By* G. CHESNEAU. *Annales des Mines*, 1900, *series* 9, *vol. xvii.*, *pages* 309-314, *with* 1 *illustration in the text.*

A slight explosion of fire-damp having been caused in a fiery coal-seam by a Mueseler lamp, the lamp was submitted to the Fire-damp Commission for investigation. It was an ordinary Mueseler, of the regulation dimensions, fitted with a Catrice relighter and a Catrice hydraulic lock. In order that the recess in the bottom-ring of the lamp-frame for receiving the bolt of the lock should coincide exactly with this bolt, a stop-block was fixed to the bottom-ring, which came in contact with a projection soldered to the oil-vessel. To ensure sufficient pressure between the top of the glass-cylinder and the horizontal gauze-diaphragm, in spite of the stoppage to the screwing-on of the oil-vessel, the upper ring of the lamp-frame fitting above the glass-cylinder was provided with two bolts pressed down by springs against the collar of the gauze, so as to press it against the top of the glass-cylinder. The failure of the lamp was due to the insufficient pressure exerted by these springs. The horizontal gauze was bound with an iron-ring and this had become contorted, so that on one side there was an open space of 0·078 inch between the top of the glass-cylinder and the gauze, notwithstanding the pressure of the spring-bolts. A further defect was due to the screw of the relighting apparatus, which, when in certain positions, prevented the glass-cylinder from fitting accurately. The occurrence shows the danger of locks with stop-blocks, and the use of springs, which may become ineffectual through unperceived weakening. The locking-stop should be replaced by a method allowing the oil-reservoir to be screwed so as to press the glass-cylinder firmly against the gauzes: this can be done by forming a rack round the under side of the bottom-ring of the lamp-frame. When the horizontal gauzes of Mueseler lamps are furnished with collars, these should not be rigid, but yield easily to a slight pressure. W. N. A.

EXPERIMENTAL STATION FOR TESTING SAFETY-LAMPS AT THE UNION EXPERIMENTAL DRIFT, BISMARCK, WESTPHALIA.

Die Versuchsstation für Sicherheitslampen auf der berggewerkschaftlichen Versuchsstrecke bei Bismarck i. W. *By* BERGASSESSOR FÄHNDRICH. *Glückauf*, 1900, *vol. xxxvi.*, *pages* 445-449, *with* 2 *plates.*

The building used for lamp-testing, 16·4 feet (5 metres) distant from the observation-station of the experimental gallery, has a total length of 312 feet

(95 metres) and a breadth of 15·4 feet (4·7 metres), divided into three rooms. The first of these serves for experiments and for an office; the second contains an apparatus for gas-analysis and a dark room for photometric measurements; whilst the third room forms a store-house for safety-lamps, wire-gauzes, etc.

The pit-gas used in these experiments comes from the dammed-off workings of a seam of bituminous coal in the Consolidation colliery. The goaf behind the dams is filled with pit-gas, which has a pressure of 1·38 inches (35 millimetres) of water. A pipe, 1·69 inches (43 millimetres) in diameter, leads the gas from the shaft to the surface and the experimental drift. A small steam-jet, in the pipe, is used to increase the velocity of the current of gas, as required. The gas mixed with steam is brought into two chambers, in which the steam is condensed, while the gas passes, cool and free from vapour, into a gasometer of 2,825 cubic feet (80 cubic metres) capacity. The bell of the gasometer is so loaded that it keeps the gas under a pressure of 5·91 inches (150 millimetres) of water; it takes from 8 to 10 hours to fill it completely. The pit-gas contains from 40 to 55 per cent. of methane, and from 5 to 7 per cent. of carbon dioxide. A portion of the latter is removed by passing the gas through a rectangular cast-iron box of about 70 cubic feet (2 cubic metres) capacity in which three horizontal wooden trays are placed and upon which quicklime in fragments about the size of a nut, is spread out. In this purifying box, the gas is freed from about 3 per cent. of carbon dioxide, so that gaseous mixtures, containing even large percentages of pit-gas, never contain more than 1 per cent. of carbon dioxide. Experiments have shown that this proportion has no perceptible effect upon the inflammability of the gases or upon the appearances presented by the flames of the lamps.

The apparatus for testing lamps, known as a Schöndorff experimental chamber, consists of a pipe 14·7 feet (4·5 metres) long, of rectangular section, 10·24 inches (26 centimetres) high, and 4·72 inches (12 centimetres) broad. It is made of sheet-iron strengthened with angle-iron. The gaseous mixture inside the chamber is put into motion by means of a Körting injector, worked with a pressure of 5 atmospheres of steam, which, with a depression of 39·37 inches (1,000 millimetres) of water, can exhaust 1,066 cubic feet (30 cubic metres) of rarified air, equal to 953 cubic feet (27 cubic metres) of air at ordinary atmospheric pressure. The exhausting action of this injector produces a partial vacuum in the chamber, and the inflammability of the gaseous mixture and the mechanical effect of explosions is decidedly decreased. A forcing fan would therefore give results more closely comparable with those obtained in the pit, but there were technical difficulties in the way of its application.

Branch pipes, entering the middle of the chamber, enable the direction of the gaseous currents to be changed, so as to direct them vertically upward, or downward as required, against the safety-lamps. In the front of the chamber are 4 openings, which can be closed by means of doors, through which the lamps to be tested can be inserted in the chamber. In each of these doors two glass plates are fixed, so that it is possible without danger to examine the behaviour of the safety-lamps that are placed within the chamber. In the upper part of the chamber, there are 4 safety-valves, consisting of hinged iron-plates made gas-tight by means of indiarubber-joints. A tube is inserted in the floor, one end of which reaches to the centre of the chamber, so that samples of gas can be taken, and which, when not in use, is closed by an indiarubber-plug. At the further end is a mixing-chamber, into which pit-gas and atmospheric air can be admitted. The pit-gas is brought into this chamber through 24 copper-tubes, 0·63 inches (16 millimetres) in diameter. In each of these tubes are 12 holes, 0·12 inch (3·

millimetres) in diameter. The pit-gas is forced through these tubes, and passes through the holes in thin streams into the air that surrounds the pipes. In order to cause the air and gas to mix as completely as possible, there are 2 rows of diaphragms built into the box, through which the gaseous current twists backward and forward; and the eddies formed in this way produce a perfectly uniform gaseous mixture.

The measurements are made by determining the difference of pressure and the velocity of flow of the gases when they are forced through an aperture in a thin diaphragm. Two water-gauges are employed for determining this difference of pressure. These are so constructed that the height of the water-column can be read off to 0·04 inch (1 millimetre) and estimated to 0·004 inch (0·1 millimetre). By determining the percentage of methane in the pit-gas, it is possible to calculate the methane-contents of a gaseous current moving through the diaphragm at a definite velocity at definite differences of pressure. These calculations have been made for mixtures containing from 1 to 13 per cent. of methane and moving with velocities of 3 to 40 feet (1 to 12 metres), and have been tabulated in 16 tables, corresponding to methane-contents of between 40 and 55 per cent. in the original gas. H.L.

THE SACCARDO SYSTEM OF VENTILATING RAILWAY-TUNNELS.

La Ventilation des Tunnels et le Système Saccardo. *By* L. CHAMPY. *Annales de Mines*, 1900, *series* 9, *vol. xvii.*, *pages* 167-215, *with* 2 *plates.*

The Saccardo system has, during the last few years, been applied with much success to the ventilation of railway-tunnels. The principle is that of a large fan communicating with the tunnel by an air-passage, and the air thus forced in under pressure is so arranged that it carries with it a large volume of the surrounding fresh air. The idea of making the air from a fan serve as an air-injector, and thereby induce a secondary current of air at a lower speed and pressure, is not new, but it was first successfully applied by Mr. Saccardo to the Pracchia tunnel in the Apennines, on the line from Bologne to Pistoie, in Italy. The tunnel is about 8,940 feet long, and has a gradient of 1 in 40. It contains a single line, and the perimeter is about 61 feet. It is in the centre of a mountainous district, near the summit of a ridge where the high wind often checks the natural current of air into the tunnel. The heavy trains burn much coal, as the Pracchia tunnel is at the top of a steep slope of nearly 8 miles, with many smaller tunnels, and 48 trains pass through it daily. Thus the working conditions are the worst possible for securing proper ventilation, and until the Saccardo system was introduced, accidents from the bad air were frequent. On a train conveying the Empress of Austria, some years ago, the driver and stoker were both asphyxiated before the end of the tunnel was reached.

The Saccardo apparatus has been placed at the higher end, and a current of air is blown down-hill, and directed against the ascending trains. The system consists of an annular chamber all round the periphery of the tunnel, connected to the air-pipe of a fan placed outside at some distance, in the open air. The chamber is prolonged on its inner side by a large air-way projecting into the tunnel, and directing the air-discharge from the fan into it. The air, thus forced in, carries along with it another current at lower pressure. The fan is of the Ser type, 16 feet in diameter.

The current of air in the Saccardo system being produced by an air-injector, a certain relation exists between the pressure of this air, the angle and speed

of the air-jet, and the speed of the current thus obtained. The powers required to produce currents of air having speeds of 6½, 13, 19½, and 26 feet per second in the tunnel, with pressures at the fan of about 0·30 inch, 1 inch, 2·5 inches, and 4·4 inches of water, were 4, 37, 124, and 300 horsepower respectively—without natural ventilating-currents. Experiments were also made with an induced draught, having a speed of 6½ feet per second. The Ser fan used at Pracchia was driven at a speed of 80 revolutions per minute, by a locomotive engine yielding 320 horsepower.

The chief cause of bad and vitiated air in tunnels is the combustion of coal for locomotives, a process which withdraws the oxygen, produces carbon monoxide, carbon dioxide, sulphurous acid, hydrocarbons, etc., and raises the temperature. Interesting details are given of the extent to which air may be vitiated by an undue preponderance of any of these gases, and yet be fit for respiration. It was found that air containing as much as 4 per cent. of carbon dioxide, and 2 per cent. of carbon monoxide could be breathed without complaints from the stoker or driver, but 3 per cent. was considered the maximum limit permissible in ordinary cases. Table I. shows the permissible vitiation of air for breathing.

TABLE I.

Noxious Gases.	Condition of Air as regards Respiration. Good.	Medium.	Dangerous.
Carbon dioxide, per cent. ...	0·62	1·35	1·84
Carbon monoxide, per cent. ...	0·34	0·59	1·23
Totals, per cent. ...	0·96	1·94	3·07

The temperature in the Pracchia tunnel was reduced by artificial ventilation to from 12° to 6° Cent. below that without ventilation, and the humidity of the air was considerably diminished. All the above causes act simultaneously in a tunnel to vitiate the air, but the experiments showed that there was no difficulty in this respect with an ordinary train, so soon as the air injected by the fan succeeded in annulling the current of air caused by the train. The theoretical consumption of coal (free from ash) was 0·032 pound per foot for the front engine, and 0·029 pound per foot for the rear engine, for a train having two locomotives.

In 1899, the Saccardo system was applied at Gœschenen to the St. Gothard tunnel. Here the problem was to drive out the products of combustion, which collect in different parts of the tunnel. A speed of 10 to 12 feet of air per second in the tunnel was taken as the maximum. The length of the St. Gothard tunnel is 49,146 feet, and its mean diameter 22·3 square feet. The arrangement is on a larger scale than at Pracchia, and for the air-chamber the whole periphery of the tunnel, even between the rails is used. There are two fans, each supplying air through a separate pipe to a special air-chamber. With the present traffic of 62 trains per 24 hours, artificial ventilation at the speed of 5 feet of air per second would allow a dangerous accumulation of noxious gases at certain places. If the speed of the air-current be doubled the air in the tunnel is 66 per cent. better. Artificial ventilation would, therefore, appear to be always necessary, even if the speed of the natural air-current is 6 feet per second, and 750 horsepower is required to produce sufficient ventilation to relieve the congestion of air in the tunnel. The fans at St. Gothard are worked by a turbine from the Reuss river. Electric locomotives may be ultimately employed.

The Saccardo system obviates the necessity of the costly and sometimes impossible method of ventilating tunnels by means of doors and galleries. It is not very expensive, the St. Gothard application having cost about £7,500.

B. D.

FIRE-DAMP EXPLOSIONS AND THE BAROMETER IN DORTMUND.

Die Schlag wetterexplosionen im Oberbergamtsbezirk Dortmund mit Beziehung auf den Barometerstand im Jahre 1899. *By* V. L. *Glückauf*, 1900, *vol. xxxvi., pages* 750-753, *with* 1 *plate.*

The results of experience and research up to the present time may be embodied in the following rules:—(1) The quantity of fire-damp found in a mine diminishes with a rise in the barometer; (2) the quantity of fire-damp in a mine increases with a fall in the barometer; and (3) this decrease or increase is quick or slow, according as the change in the barometer is sudden or gradual.

The author closely investigates the causes, etc., of the explosions for the year 1899 and finally notes that of the 35 explosions 32 were fire-damp explosions and 3 fire-damp and coal-dust combined; moreover, only 26 per cent. of these 35 explosions occurred when the barometer had a tendency to fall or was already low, that is to say 74 per cent. of the explosions occurred when from the above rules the presence of fire-damp was not to be expected.

Table I. shows the relations of the explosions which have occurred since 1891.

TABLE I.—EXPLOSIONS AND THE BAROMETER.

Year.	Number of Explosions	Low.		High.		Rising.		Falling.	
		No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
1891	86	46	53	40	46	54	62	32	37
1892	75	22	30	53	70	45	60	30	40
1893	70	28	40	42	60	37	51	33	49
1894	60	18	30	42	70	32	53	28	46
1895	48	23	48	25	52	28	58	20	41
1896	42	18	43	24	57	27	64	15	35
1897	61	27	44	34	56	30	50	31	50
1898	42	17	40	25	59	21	50	21	50
1899	35	20	57	15	43	16	45	19	55
Totals and Averages	519	219	42	300	58	290	56	229	44

The rapid diminution in the numbers of the explosions is noteworthy. The chronicling of the direct causes of each explosion enables the author to say that 54 per cent. of the explosions were due to gross carelessness or disobedience to well-known mining regulations.

Finally, there is very little statistical proof or confirmation of the rules respecting the connection between barometrical variation and explosions, and consequently explosions cannot even in a single case be foretold either by the behaviour of the barometer or by any other method. C. H. M.

TWO NOTEWORTHY EXPLOSIONS IN PRUSSIAN COLLIERIES IN 1899.

Mittheilungen über einige der bemerkenswerthesten Explosionen beim Preussischen Steinkohlenbergbau im Jahre 1899. ANON. *Zeitschrift für das Berg-Hütten- und Salinen-Wesen im Preussischen Staate*, 1900, *vol. xlviii., pages* 504-507, *with plans in the text.*

1.—The fire-damp explosion which took place at the Preussen colliery, East Dortmund district, on the afternoon of July 1st, 1899, resulted in personal

injury to 2 miners, one of whom afterwards died from the effect of the serious burns which he had sustained.

The scene of the disaster was the No. 2 level (1,785 feet belowground) where No. 20 seam, 44 inches thick, of the Esskohlengruppe has been worked for a few years. The seam dips 50 to 55 degrees, is not especially fiery or dusty, and the normal humidity of the workings is usually sufficient to lay such dust as does arise. In the main crosscut, a blowing ventilator, driven by compressed air, had hitherto proved amply capable of keeping the atmosphere clear of accumulations of fire-damp. Apparently the 2 victims were engaged in extending the ventilating-pipes into a newly opened drift. One of the men had extinguished his safety-lamp, while the other had slung up his, still alight, in a place seemingly clear of gas, at about the height where the ventilating-pipe debouched. The pit-gases, driven downward by the outrush of air through the pipe, caught fire at the safety-lamp that was still alight, and scorched severely the man who stood below, while his comrade who was standing at a point some 10 feet higher sustained only slight burns.

The character of the coal in this part of the workings differed from the normal: it was soft and crumbly, and exhibited a tendency to fissure, the split surfaces being covered with a velvety brown layer.

In the neighbouring Gneisenau colliery, these characteristics invariably denote the presence of accumulations of fire-damp, which suddenly burst forth when the fissures are laid bare.

2.—A more disastrous explosion took place at the Reden colliery, in the Bonn mining district, in the forenoon of September 16th, 1899, resulting in the death of 9 persons.

Here in the No. 2 deep level, the Heiligenwald seam is worked: it is regularly bedded, dips 14 degrees northward, and consists of three layers of coal, respectively 39, 31 and 37 inches thick, between which intervene two shaly partings, respectively 13 and 4 inches thick. The coal is tough, and gives rise to extremely little dust, what little there is being always laid by the natural moisture of the workings. No evolution of gas had been noticed hitherto when going through the workings with benzine safety-lamps. Only the two lower seams of coal were worked, the uppermost or 37 inches bed, having too bad a roof. Ample ventilation, far exceeding the minimum required by the regulations, was provided by three ventilators driven by compressed air.

In the night of September 15th to 16th, two shot-holes had been drilled in the lowest seam, safety blasting-cartridges had been inserted in them, and the fuse in the lower hole was ignited. After the lower shot had been fired, the fuse in the upper hole was ignited about 4 a.m., and as soon as it began to spark, a reddish-white flame darted forth, and spread downward. As the shot was momentarily expected to take effect, no immediate attempt to extinguish the flame could be made. When the shot had exploded, the flame seemed to vanish from the working-face, but reappeared after some broken-down coal had been shovelled away from the latter. By dint of heaping up coal on the burning stuff, the flame seemed to die down; and the shovelled coal in turn catching fire was extinguished by means of water brought to the spot in buckets. The conflagration being to all appearance at an end, the workpeople were withdrawn from that particular place, and the ventilator was driven at a higher speed, in order to expel the noxious gases. But, on returning ½ hour later, the workpeople observed smoke still arising from the shovelled coal, so water was once more thrown upon it (being brought in iron tubs from the bottom level), and the ventilator was again

run at a heightened speed. Nevertheless, it was found impossible, after another ½ hour interval, to work at the face, as the coal was burning so strongly. Orders were then given to shut off that portion of the workings by two masonry stoppings. This operation was all but completed, when, about 10·30 a.m., a fire-damp explosion in the walled-off area took place, smashing up the masonry and the timber-doors, and hurling huge masses of them 100 feet or so into the haulage-way. The 3 men who were still working at the dam and their overman and 5 men (whose shift was completed) who were sitting down near the shaft, waiting for the cage to take them to bank, were all killed by the flying fragments.

No coke-crust nor coke-beads were found in the radius affected by the explosion, and the after-damp only rose to a height of 20 inches or so, thus showing that coal-dust had no share in the catastrophe, and that the amount of fire-damp involved cannot have been great. The damage was considerable, because the explosion took place in a completely enclosed area. L. L. B.

EXPERIMENTS WITH THE NEUPERT AND THE PNEUMATOPHORE RESCUE APPARATUS.

Versuche mit O. Neupert's Nachfolger Rettungsapparat, nebst einem vergleichenden Versuch mit dem Walcher-Gärtner'schen Pneumatophor. By DR. RICHARD HELLER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1898, *vol. xlvi., pages* 297-302.

These experiments were mainly directed to determine the effect produced by the apparatus on the respiration and arterial circulation of the wearer, and also whether any pathogenic symptoms are occasioned:—

Experiment 1.—Air from the apparatus analysed by the Orsat method. Duration of experiment, 2 hours; room temperature, 11° Cent.; consumption of oxygen per hour, 2,440 cubic inches (40 litres); pulse, 80 to 82 per minute; respirations, 24 per minute. Carbon dioxide and oxygen in air drawn while the wearer was breathing, 3·6 per cent. and 20·2 to 26·4 per cent.; with arrested breathing, 0·4 to 1·1 per cent. and 14·0 to 27·6 per cent. respectively. The wearer remained quiet, doing no work. There was no facial perspiration and no discomfort.

Experiment 2.—Here the temperature was 12° Cent., and the consumption of oxygen, 175 cubic inches (28·7 litres) per hour. The wearer worked a rotary pump, but did not perspire in the face. Pulse, 80, increasing to 90 after 1 minute's work; respirations, 22 to 28; air-content: carbon dioxide, 1 to 3 per cent., average 1·4 per cent.; oxygen, 13 to 27·4 per cent., average, 21 per cent.

Experiment 3.—In this case, the samples of air were taken from the mask; time 2¼ hours; temperature of air, 16° Cent., of mask, 33° Cent.; oxygen consumed per hour 2,440 cubic inches (40 litres); pulse, 80 to 87; respirations, 20 to 32; carbon dioxide in air-bag, 3·2, rising to 8·2 per cent., mean, 3·4 per cent.; oxygen, 6·5 to 46 per cent., mean, 19 per cent. The supply of oxygen was varied, but the effect was not so favourable as with a constant smaller supply. As the percentage of carbon dioxide decreased towards the end, respiration became slower. The rate of increase when the wearer began to work was normal, as also the pulse.

Though the air-samples were taken at various stages of respiration the average composition fluctuated not more than 0·3 per cent.; the amount of carbon dioxide in the expired air was normal (4·5 per cent.) and no

symptoms of carbon-dioxide poisoning were observed. The air temperature inside the mask did not exceed the normal (36° Cent.), and no deposit of moisture was formed.

The oxygen-consumption may vary within wide limits, 7 to 87 per cent. of the inspired air, the first-named being the lowest that can be used with safety. If the oxygen-supply be reduced and the carbon dioxide allowed to increase, pathogenic symptoms will arise, a contingency prevented by the absorption of the latter gas in the apparatus.

Under similar experimental conditions, the results obtained with the pneumatophore were somewhat different, the pulse registering 80 to 100; respirations, 20 to 32; carbon dioxide in air-bag, 3·2, rising to 8·2 per cent., and inducing increased pulsation and respiration, thus indicating defective absorption by the caustic soda employed. The wearer complained of headache after three hours. C. S.

DEVELOPMENT AND RESULTS OF RESCUE-WORK IN MINES

Entwicklung und Erfolg des Rettungswesens beim Bergbaubetriebe. *By* HUGO RÖSSNER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 519-522 *and* 531-534.

Constant practice in the use of rescue-appliances being essential to success in an emergency, the custom, at Karwin, is to drill 10 per cent. of the working staff (including a few mechanics) with the oxygen-apparatus, ambulance-work, tearing-up tram-rails, taking-down and setting-up air-doors, etc., both in the ordinary pit-atmosphere and in irrespirable gases. It is found that the men are better able to stand the fatigue of working with the apparatus after a meal, and all rescue-parties in future will be provided with refreshment before entering upon their task.

The alleged danger arising from the expansion of the oxygen in the oxygen-bottles of the rescue-apparatus, under the influence of heat (as in the case of a pit-fire), is found to be negligible, since the rate of expansion is only about 0·4 per cent. per 1° Cent., so that even in case of an increase of 50° Cent. in temperature the expansion of gas in the bottles (which hold 3,660 cubic inches (60 litres) of compressed oxygen) is only equivalent to 671 cubic inches (11 litres), or an increase in pressure from 100 to 118 atmospheres, whereas the bottles are tested up to 250 atmospheres.

The volume of air consumed at the rate of 20 respirations per minute, being equivalent to about 18·3 cubic inches (0·3 litre) of oxygen when no work is being done, with an additional 0·183 cubic inch (0·003 litre) for each kilogrammetre of work exerted, it follows that with medium work, the oxygen-consumption is 73·2 cubic inches (1·2 litres) per minute; and the oxygen-supply (3,660 cubic inches or 60 litres) will last for 50 minutes under these circumstances, or for 200 minutes if the wearer be at rest. The caustic-soda bottle holds 26 cubic inches (0·425 litre) of caustic soda, sufficient to absorb 2,904 cubic inches (47·6 litres) of carbon dioxide, and will therefore suffice for a working period of 42 minutes, or 168 minutes if no work is being done. During the first ½ hour the rate of breathing is normal—8 per minute—but increases to 9 respirations after 1 hour, owing to the slight stimulative effect of the oxygen. The pulse exhibits a decrease from 85 beats to 80 after about 10 minutes, during gentle work.

Analysis of the gas in the air-bag after 8 minutes' use shows the inhaled air to consist of: oxygen, 48·5 per cent.; carbon dioxide, 4·4 per cent.; nitrogen, 47·1 per cent.; the oxygen decreasing to 44·5 per cent. after 53

minutes, and to 15·8 per cent. after 1 hour 46 minutes, when the wearer is at rest. When work is being done, the oxygen-content is different, namely, 25·6 per cent. after the first 14 minutes; 20·1 per cent. at the end of 1 hour 50 minutes; and 8·8 per cent. after 2 hours 6 minutes. The large amount of nitrogen present is introduced from the inflated lungs of the wearer, and to a smaller extent (4 to 6 per cent.) with the oxygen-supply. C. S.

RECHARGING APPARATUS FOR THE OXYGEN-BOTTLES OF RESCUE-APPLIANCES.

Vorrichtungen zum Nachfüllen der Sauerstoff-Flaschen bei den Rettungsapparaten. By JOHAN MAYER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 409-412, *with* 1 *plate.*

To remove the difficulty experienced in recharging oxygen-bottles that have become depleted by leakage, etc. (the pressure in the storage-cylinders being after a time insufficient to fill the bottles at anything like 100 pounds), Messrs. O. Neupert's Nachfolger have brought out an apparatus for this purpose. It consists of a pump, whereby water is forced into the oxygen storage-cylinder, in consequence of which the gas can be compressed to any desired extent. A pipe in the stopper of the cylinder conveys the gas through a purifier into the oxygen-bottle to be filled. The whole apparatus is mounted on a solid frame, forming the water-tank. Owing to absorption of oxygen by the water, the loss of gas is about 3 per cent.; but part at least of this loss can be recovered by warming the water. C. S.

THE PNEUMATOPHORE AND ITS LIMITATIONS.

Die Benutzung des Pneumatophors im Ernstfall. By BERGASSESSOR LÜTHGEN. *Glückauf*, 1900, *vol. xxxvi., pages* 593-595, *and* 1 *plate.*

On March 11th, 1900, at Recklinghausen colliery, two miners, who were using the pneumatophore in an atmosphere of inflammable gases, met with their death. This occurrence, coupled with certain other unfavourable experiences in connection with the pneumatophore recorded from other localities, might create prejudice against its further use; but the author points out that precisely at this Recklinghausen colliery, in the course of the operations necessary for extinguishing the fire which had broken out on March 10th, the pneumatophore rendered very great service.

The two men (brothers) who perished had been sent forward to investigate the condition of the atmosphere near the original seat of the fire (after various measures of ventilation, etc., which the author fully describes, had been taken), but had been forbidden to go on through the smoke. The pneumatophores, however, had proved so reliable that the two men exceeded their orders, and went on as far as ½ mile through the escaping gases, and that with incompletely-filled oxygen-holders, a fact of which they were fully aware. Twice they went this distance in thick smoke, and their bodies were found about 100 feet apart near the ventilating-doors in the Marie seam: had they but got behind these, they would have been saved. As the temperature of this portion of the pit was at that time about 122° Fahr. (or more) it is uncertain whether the heat and excitement combined caused the two victims to faint away, and that then the residual oxygen simply escaped from the holders, or whether their death was due to the exhaustion of the supply of oxygen in the apparatus. The latter alternative appears doubtful to the

author. He remarks that it would be strange if, in the case of partly used apparatus, the supply of oxygen in both holders should fail at the same moment precisely; and moreover one of the brothers was known to consume far less oxygen in using the pneumatophore than the other.

He concludes that the pneumatophore is an almost indispensable auxiliary in certain clearly defined, restricted cases; but that we must beware of exaggerating its value. In actual use, more oxygen by far is consumed than in the rescue-drill or rehearsals, which take place now and then in order to accustom the pitmen to handle it.

However little the apparatus may have been used, if it is required in a case of serious necessity, the oxygen-holder must be refilled completely. Two officials at least, who in no case should go down the pit, should be entrusted with the care and supervision of the safety-apparatus and stores. A large stock of oxygen should be kept, so that the holders may never be placed in the pneumatophore with a less quantity than 5,500 to 6,100 cubic inches (95 or 100 litres) of the gas. Finally, the fatality thus described is a stern warning to miners of all degree never to exceed the orders which they receive.

L. L. B.

SPONTANEOUS COMBUSTION OF COAL-CARGOES.

(1) *New South Wales: Report of the Royal Commission appointed to inquire into the Cause of the Dangers to which Vessels carrying Coal are said to be peculiarly liable, etc.*, 1897, *pages* 1-5, 1-87 *and* 1-105, *with illustrations in the text and* 1 *plate.* (2) *New South Wales: Report of the Royal Commission appointed to make further Investigation, etc.*, 1900, *pages* 1-28, *with* 6 *diagrams.*

Owing to increased casualties to shipping during the southern summer of 1895-1896, the first Commission was appointed in July, 1896, by the New South Wales Legislative Assembly. The danger of spontaneous combustion of coal-cargoes occupies a large part of the report which was presented in May, 1897. The second Commission was appointed with instructions to more particularly investigate the influence of moisture as a factor of spontaneous combustion, and the result is set forth in the report presented in March, 1900. Both reports contain the record of an independent inquiry which was commenced at the pit, carried into questions of transit, loading, trimming, and into the effect of the sizes and arrangement of cargoes. Many experiments were carried out, testimony was gathered in all directions, and copious reference is made to the more important literature of the subject, so that the first report, to some extent, is a bibliography with regard to the spontaneous combustion of coal.

1.—The theory of spontaneous combustion arrived at by the first Commission is one of the simpler forms of the well-known oxidation theory. Coal absorbs the atmospheric oxygen; absorption of oxygen by coal develops heat; the developed heat, if confined, raises the temperature, and the rise of temperature in turn facilitates, and accelerates the rate of, the absorption of oxygen. The two conditions which bring about spontaneous combustion, therefore, are a sufficient supply of oxygen and a sufficient confinement of the heat thereby developed. To a large extent, the two conditions are incompatible. The ratio of the absorption of oxygen depends on the ratio of the exposed surface to the volume of coal. In a heap of fine coal-dust, the ratio of surface to volume is very large; but a heap of very fine dust is almost impenetrable by the oxygen. On the other hand, if the coal be in large pieces, the air easily penetrates the interspaces, but the absorbing surface is

very small relatively to the volume to be heated. The most favourable conditions for heating occur when heaps of moderately lumpy coal are mixed with certain quantities of fine coal-dust. Such heaps are found under the hatchways of ships loaded by dropping the coal from hoppers, spouts, etc. And the Commission state that out of many hundred cases of known spontaneous heating, there is not one but was found in the square of one of the main hatchways. In every case of spontaneous combustion investigated by the Commission, the mode of loading ensured a cone of broken coal in the square of the hatchway, and they recommend "that the cranes be altered so as to admit of the waggons being lowered down the hatchways with a view to minimize the breakage of coal."

Spontaneous combustion of coal-cargoes being due to absorption of oxygen and the consequent rise in temperature, the Commission lay great stress on the suggestion that ships loaded in hot weather are more liable to spontaneous combustion than those loaded in cold weather. The rise of temperature due to absorption of oxygen usually proceeds very slowly, and the voyage may be made and the cargo discharged before the critical point of temperature is reached. But a ship loaded in hot weather, directly under the solar rays, receives a cargo having a high initial temperature, and the critical point will be much sooner attained. With regard to the increased casualties by spontaneous combustion during the summer of 1895-1896, the statistics show that every one of the ships so suffering was loaded in exceptionally hot weather, the end of 1895 and the beginning of 1896 being one of the hottest periods ever known in the colony. The Commission also draw attention to the fact that no ship loaded with Newcastle (N.S.W.) coal in June or July (the Antipodean winter) has ever found its cargo heating. The same facts point to the inference that the liability of a coal-cargo to spontaneous combustion increases with the length of the voyage, the average temperature of the voyage, and the temperature (artificial or otherwise) of the enclosure containing the coal. The Commission recommend "that very large ships should not be loaded with the existing appliances on days when the maximum shade-temperature rises above 80° Fahr., or the maximum sun-temperature above 110° Fahr."

The reference to very large ships in this last recommendation is due to the fact that the liability of a coal-cargo to spontaneous combustion increases very rapidly with the depth of the ship. The British Commission of 1876 suggested this condition, but the labours of the New South Wales Commission resulted in placing the axiom beyond all possibility of doubt. Taking the sailing shipments to America from 1888 to 1896, there were 152 cargoes under 1,000 tons each, and not one of these fired or heated; of 1,454 cargoes ranging from 1,000 to 2,500 tons, 3 either fired or heated; of 276 cargoes above 3,000 tons, 10 heated, or nearly 4 per cent.; whilst of 22 cargoes above 4,000 tons, 4 either fired or heated, being a proportion of 18 per cent. That this variation of the liability is due to depth alone appears clear from the following evidence from another source: The Australian Gas Company has two coal-stores: at both, the circumstances, with one exception, are exactly the same. The exception is that one is kept filled with coal to a depth of 14 feet only, while the other is kept filled to a depth of 20 feet. The shallower store requires no attention, no spontaneous heating having ever appeared therein, while the deeper store requires constant watching to prevent the coal from firing.

The Commission make no independent or precise pronouncement as to the class of coal most liable to spontaneous heating, neither do they attach

importance to the presence of iron-pyrites. With respect to the ventilation of coal-cargoes, they recommend that surface-ventilation only should be employed.

2.—The second report deals more particularly with the influence of moisture on the liability to spontaneous combustion. To test the matter, the Commission erected two large bins, each designed to contain a cubical mass of coal, 21 feet in the side. Every care was taken to make the conditions in and about each bin the same as those obtaining in and about a vessel carrying coal. The two bins were loaded as nearly as possible simultaneously, in order to equalize all conditions. The distance through which the coal fell was at first 17 feet, gradually lessening as the bins became full. The same class of coal was used in each bin. One bin was loaded dry, and the other was loaded wet. When loading the coal into the wet bin, a stream of fresh water from a hose was continuously played over it in such a way as to thoroughly saturate it. The quantity of water used was sufficient to cause a small stream to flow from the bottom of the bin, but not sufficient to wash out any considerable quantity of fine dust. For the purpose of taking temperatures, thirteen thin galvanized-iron pipes about 2 inches in diameter and 0·018 inch wall-thickness were placed vertically in each bin prior to loading.

The bins being full on December 2nd, 1898, temperature-readings were taken at intervals. The temperatures in the dry bin rose very rapidly until February 13th, 1899, when at 8 feet from the surface in the centre tube, the temperature was so high that the solder-connections of the thermometer were melted and the instrument lost. At 4 feet below the surface in this central tube, the temperature was 135° Cent., but other experiments indicated that the maximum temperature was 8 feet from the surface. In all the other tubes the temperature was much lower, the highest being 87·7° Cent. It was decided not to risk a fire by prolonging the experiment with the dry bin, and on this date the bin was flooded and all the hot coal removed. On digging down, the heat seemed to be confined to a spot immediately in the vicinity of the central pipe. So far as the wet bin was concerned, the experiment was continued, and the temperatures taken until April 30th, 1899, but this bin gave absolutely no signs of heating, and from January 27th onward there was a steady decline in the mean temperature. To the question the Commission set out to solve, therefore, they return "a direct and unconditional answer. Coal is less liable to spontaneous combustion when it is loaded wet than when it is loaded dry."

The Commission dispose of the findings of the British Commission of 1876 as follows:—"The British Commission received 26 answers to the effect that wet coal was the more dangerous. But an analysis of the evidence discloses that 25 of these answers were based on 'general impression' or hearsay evidence only, while the 26th was not tested by cross-examination. The opinions referred to were held, not by scientific men, but by those engaged in the coal-trade. . . . . All such views, it seems to us, must now be definitely abandoned."

The report concludes with the following recommendation:—"Having in view the fact that cases of spontaneous heating invariably occur in the heap of small coal under the hatchways, and in the light of the foregoing conclusive result, we recommend that when large ships are being loaded during warm weather (say, when the air-temperature is 90° Fahr. or over) a hose should be played down the hatchways so as to wet, at all events, the coal which collects at that spot."

X. Y. Z.

UNDERGROUND PUMPING-ENGINE AT THE ETTES SHAFT, NORTHERN HUNGARY.

Unterirdische Compound-Wasserhaltungsmaschine am Ettester Schachte der Nordungarischen Vereinigten Kohlenbergbau- und Industrie-Actien-Gesellschaft. *By* STEFAN STEUER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 341-344, *with* 1 *plate.*

The pumping-engine, which is set up about 7·4 feet (2·25 metres) above the loading-place, and is designed to lift an average volume of 330 gallons (1,500 litres) of water per minute against a head of 722 feet (220 metres), is of the tandem type and works at a boiler-pressure of 6½ to 7 atmospheres. The differential-plunger force-pump, fitted with Riedler valves, draws water from a reservoir in front of the engine, the supply being maintained at a constant level by an accessory pump which lifts from the sump 13 feet (4 metres) below the loading-place.

The dimensions are as follow:—Diameter of high-pressure cylinder, 19·68 inches (500 millimetres); low-pressure cylinder, 31·49 inches (800 millimetres); ram-pump plunger, 10·23 to 7·22 inches (260 to 184 millimetres); common stroke, 23·62 inches (600 millimetres); diameter of pistons of air and accessory pumps, 21·65 inches (550 millimetres); stroke, 11·81 inches (300 millimetres); speed 50 to 67 revolutions per minute.

A special valve is fitted in the rising-main pipe to prevent a return-flow of water to the ram-pump, and opens automatically when the pump is started. The air-pump for charging the air-vessel of the pump is driven from the expansion-eccentric, and the clearances are cooled and filled with water by a spray introduced from an annular chamber in the stuffing-box *via* a bore in the plunger.

The high-pressure cylinder is bolted on the bed-plate, the low-pressure cylinder being supported by wrought-iron stays. The piston-rod is in two parts, but as the front head of the low-pressure cylinder is screwed on from the inside, the rod, pistons and cylinder-heads can be drawn out together.

A modified form of Corliss valve-gear devised by Mr. F. Struad is used for the high-pressure cylinder, the expansion-valves being mounted concentrically inside the main valve, so that the alterations in the cut-off are determined by the relative displacement of the valve-edges. One eccentric drives the four slide-valves, while a separate eccentric works the expansion-valves of the high-pressure cylinder through a swinging-lever, which also serves for the expansion-adjustment.

When tested after 5 months' work, the engine gave satisfactory diagrams; and, owing to the insulation of the steam-pipe with silk-waste and zinc, the loss by condensation was found to be slight. C. S.

ERECTING A CONCRETE DAM IN A MINE AT PRIBRAM.

Ueber den Bau eines Betondammes am 18. *Laufe des Lillschächter-Ostschlages in Pribram.* *By* W. OPPL. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1900, *vol. xlviii., pages* 33-36, *with* 1 *plate.*

This dam was constructed in the No. 18 level of the Lill shaft, in order to keep back the water draining from abandoned workings, which water accumulated at the rate of 28 gallons (127·5 litres) per minute and constituted 20 per cent. of the entire quantity in the mine. The form adopted was that

of a double arch of brickwork with an intervening space of 80 inches (2 metres) filled with rammed cement-concrete, the arch nearest the water being concave, and 1½ bricks thick, whilst the front arch was made 60 inches (1·5 metres) thick and built of slag-brick set in cement-mortar, the convex side facing the pressure.

The site chosen for the dam was in a bed of diorite, 197 feet (60 metres) east of the loading-place, the gallery being widened and heightened by 40 inches (1 metre) each way for a distance of 13 feet (4 metres) so as to form conical abutments for the two brick arches, and a double cone for the reception of the cement-concrete. This work was performed by careful blasting with small charges of dynamite in short holes, to prevent the undue shattering of the rock; and a provisional dam of rammed clay was erected to keep the sole dry while the preparatory work was performed.

When the brickwork had been laid to a height of 20 inches (50 centimetres) above the gallery-floor, a channel 20 inches (50 centimetres) wide and 12 inches (30 centimetres) deep was left in the centre for the reception of the cast-iron drainage pipe 13 feet (4 metres) long and 4·72 inches (12 centimetres) in diameter, which was set in rammed cement-concrete both in the brickwork and also right through the intervening space. The arches were then continued up to a height of 7·2 feet (2·2 metres) above the floor, care being taken to fill the joints between the brickwork and the rock-abutments with rammed cement-concrete, after laying every second course.

The concrete was prepared from 1 part of Königshof portland cement, 2 parts of granulated blast-furnace slag, and 4 parts of quartz-gravel; but owing to lack of room for mixing, the concrete had to be made in 40 blocks instead of in a single mass. To prevent contact of the gravel with the rock-walls, the edges were laid in cement-mortar. The hardened surfaces of the blocks were moistened and roughened before laying the next course, in order to ensure thorough adherence. The blocks nearest the water-side of the dam were put into position first, the bricks of the upper course being pushed into place from behind and backed up by the cement-concrete, after which the rest of the concrete was laid, the upper portions being rammed against the walls, from the centre. In making up the front dam, the joints in the final course were rammed tight with cement-concrete.

The time occupied in the preparatory work was 374 shifts of 8 hours, and the erection of the dam took up 394 shifts, 2 masons and 2 labourers being engaged in each shift.

To withstand the anticipated heavy pressure (40 atmospheres), the valve in the outlet-pipe was stayed against the wall-timbers by means of strong angle-irons, wrought-iron bands being laid over the flanged joints between the valve and the pipe, for the same purpose. C. S.

A MINE-DAM.

A Mine Dam. By WILLIAM KELLY. *Transactions of the American Institute of Mining Engineers*, 1897, *vol. xxvii., pages* 400-404.

A stream of water was tapped in an exploring drift, 780 feet below the surface at the Currey iron-mine, at Norway, Michigan. The drift, which was 6 feet wide by 7½ feet high, had crossed some slate and entered a jasper formation. The dam was built in the slate, as being more dense and solid, though much softer than the jasper. It was constructed of sandstone and mortar (1 part of cement to two parts of sharp sand), 10 feet thick, and curved to a

radius of 6 feet. The abutments were cut out of the sides in line with the centre of the curve, but leaving the rock rough. The floor was excavated, 15 to 20 inches, below the bottom of the drift, and the top was made 2 feet higher in front and 5 feet higher at the back. The front courses of stone were cut to fit the arch and no crevices were left.

Two openings were left through the dam: one was fitted with a pipe 15 inches in diameter, with a gate-valve at the outer end to carry off the water, and the other with a steel pipe, 20 inches in diameter, with a blank flange, 2¼ inches thick, at the outer end, into which an hydraulic pressure-gauge was tapped. The pipes were anchored to the masonry by 3 clamps.

When the water had been shut off for about 20 hours, the gauge showed a pressure of 240 pounds and the dam was leaking 30 gallons of water a minute. The water was then let off again and a brickwall, 22 inches thick, was built, 2 feet 2 inches from the inside of the dam: the space between was filled with concrete made from limestone broken to egg-size 4 parts, with 3 parts of cement-mortar. Before shutting off the water, three loads of horse-manure were put against the brickwork, and held there by a timber partition. In a week, the pressure rose to 277 pounds per square inch, or a total pressure of more than 800 tons against the dam. The water trickling through the dam, in eight or ten different places, mostly near the top or one side, gradually decreased from 7 to 2¼ gallons per minute. After the dam was closed, the record of the pumps for six days showed a decrease of 295 gallons per minute.

The total cost of the dam was £96 (484·27 dollars). A. W. G.

WATER-AND-FUEL ECONOMY IN STAMP-MILLING.

By A. W. Warwick. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxix., pages* 529-530, *with* 1 *illustration.*

Economy of water is so essential to mining in the arid zone of Arizona and southern California that the efficiency of the water-saving apparatus frequently determines the success or otherwise of the entire operations. The result of this condition is that ore-milling is conducted with seemingly small quantities of water. The successful introduction of oil-engines has largely assisted in effecting this necessary economy.

At the Matterhorn mine, in the south-eastern corner of the Mojave desert, the writer has obtained some facts and figures as to the minimum amount of water that will supply a mill of 10 stamps. The amount was surprisingly small, and the purity of the water returned to the battery exceeded the most sanguine expectations. It was originally intended at this mill to use spitzkasten only for the water-saving apparatus, but in no case did the saving exceed 45 per cent. in the tests of the spitzkasten alone. In the first tests, the so-called "siphon-discharge" was used, but in this case, in order to prevent clogging, the effluent slime must contain not less than 80 per cent. of water. The siphon was then replaced by an adjustable gate, and this worked admirably for a time, giving slimes of any desired consistency. The coarse sands, however, gave considerable trouble, so a sandbox was placed before the spitzkasten to relieve the latter. The result of this arrangement was that the spitzkasten regularly delivered its slime, and the final saving of water averaged nearly 80 per cent.

After giving details of this arrangement and tabulating the results of a month's working, the writer refers to the importance of suitable motive power, and remarks that as the amount of water sent to the mill for the month referred to would have barely supplied the boiler had a steam-plant been adopted, it

can easily be seen how important it is to select the right motive power. This mill was actuated by an oil-engine, which gave entire satisfaction. The engine is described, and figures are given showing that in the circumstances referred to, the economy of the oil-engine is excellent compared with small steam-engines. Taking all points into consideration, a desert mill, in spite of water-economizing, can be run very cheaply, and there is no doubt that the use of oil-engines has very largely contributed to this result.

X. Y. Z.

SLATE-QUARRIES OF ANGERS, FRANCE.

Notes sur les Ardoisières d'Angers. By JOSEPH KERSTEN. *Annuaire de l'Association des Ingénieurs sortis de l'École de Liége*, 1900, *series* 5, *vol. xiii., pages* 237-253, *with* 1 *plate and* 4 *figures in the text.*

The slates of Anjou are of Ordovician age, and occur associated with grits and ferruginous shales. Their strike is east and west, and they are sharply folded into anticlines and synclines, running in the same direction. The shearing to which the beds have been subjected is shown by the deformation of the fossils, chiefly trilobites, which are found in them. The proper colour of the slaty members of the series is violet-black, but on nearing the surface they are wine-red. The cleavage of the beds worked is on the whole very perfect, slates not more than 0·08 to 0·12 inch (2 to 3 millimetres) in thickness being easily obtained, and where the dip is nearly vertical the cleavage appears to be parallel to the bedding. Three kinds of troubles disturb the uniformity of the rock. These are known locally as *torsins* or true faults of some width filled with crystalline quartz, *cordes de chat* or narrow fissures likewise filled with quartz, and *chauves* or secondary planes of cleavage crossing the normal direction diagonally.

The chief slate-beds worked are 262 feet (80 metres) at La Grand'Maison, 656 feet (200 metres) at Misengrain, and 98 feet (30 metres) at Renazé. At the first-named locality, which is most fully described in this paper, the deposit is won by means of a shaft sunk in the vertical slaty rock to a depth of 984 feet (300 metres). From the bottom of this shaft a main-way is driven along the strike and therefore also parallel to the cleavage: and from each side the slate is mined by overhand stoping in chambers, 164 feet (50 metres) long, 92 to 98 feet (28 to 30 metres) broad, and 33 feet (10 metres) in height. Except where there are disturbances, no timbering is required, it having been ascertained by experiment and calculation that a vault of compact, vertically fissile rock of the kind in question is capable of supporting a column of the above horizontal dimensions and 2,952 feet (900 metres) high without detachment taking place by slipping. The chambers at each stage are filled with waste when the slate has been withdrawn from them. The present workings at Grand'Maison from 984 feet (300 metres) to the upper portion of the unaltered slate, producing yearly 60,000,000 slates (or 1,500 tons of finished produce), are calculated to last 48 years. When these are worked out, the same process of extraction will be carried out at a lower depth. At the mine mentioned only 14 per cent. of the rock extracted is turned out as saleable slate.

The *Société Ardoisière de l'Anjou* is the principal company exploiting the slate. It employs 1,760 workmen at a wage of 2s. 1d. to 3s. 9d. (2½ to 4½ francs) a day. 65 clerks and others, and produces annually 150,000,000 slates weighing 50,000 tons. The approximate value of this output is £130,000 (3,250,000 francs).

G. A. L.

THE IRON-INDUSTRY IN LOMBARDY.

Studie über die Eisenindustrie in der Lombardie. *By* C. VON ERNST. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 381-387 *and* 400-404, *with* 1 *plate.*

A portion only of the ironworks in Lombardy is engaged in smelting indigenous ore, and this branch of the industry was never extensive, the maximum production in the most flourishing period (40 to 50 years ago) not exceeding 13,000 tons of crude iron, or 9,000 to 10,000 tons of refined iron and steel. The fall in prices after the boom in 1872-1874 struck a further blow, and, as no assistance was afforded by the 1887 tariff, the output sank continuously, so that from 1892 down to the present time only about 5,000 tons of crude iron have been turned out every year.

There are five centres of the iron-ore mining industry in the Lombard Alps, namely, Val Trompia, Lake Iseo, the middle Camonica valley, the upper Scalve valley, and Manina (upper Val Seriana). The geological formations containing the ore are:—the Lower Triassic Servino (marl-slate and sandstone-beds), the underlying Red Sandstone, and the mica-schist, all of which enclose lodes and beds of spathic ironstone.

At Pezzaze, in the Trompai valley, there are two chief lodes in the mica-schist. The Bandiera lode crops out in an east-and-west direction, with a dip of 70 degrees towards the north, and is of variable thickness, averaging about 14 inches (0·35 metre). The old workings were driven at the richest parts of the outcrop, but the expense of driving cross-cuts through the barren rock precludes the idea of getting out the deeper parts of the lode.

Further north is the second main lode (Regina) cropping out at the Regina-Zoie mine. It averages 24 inches (60 centimetres) thick; and contains, in places, copper-pyrites and grey copper-ore up to 4 inches (10 centimetres) thick. The ore is of lower quality than that from the Bandiera lode and less productive. The best iron is obtained from the siliceous ore, locally known as *morelli*.

In the same valley, the Trias formation contains three workable sedimentary deposits close together and having an aggregate thickness of about 14 feet (4·25 metres) of spathic ironstone. Owing, however, to the frequent occurrence of barren places and faults, this deposit has not been very extensively worked. The iron obtained is of inferior quality, and only one mine is now worked to supply the Tavernola blast-furnace.

In the other four districts, the output is insignificant.

The local charcoal blast-furnaces are small, being only of 423 to 495 cubic feet (12 to 14 cubic metres) capacity, and producing 3 to 4½ tons of crude iron *per diem*. The largest is at Castro and turns out 8 to 10 tons in 24 hours. This furnace and that at Tavernola are the only two employing horizontal blowing-engines and working with a pressure of 12 to 14 inches (30 to 35 millimetres) mercury-gauge, though other works are making improvements on their old-time practice.

It is considered probable that the production of good crude iron for founders' use and white iron of the spiegel type would be profitable, but it is very doubtful whether it would pay to replace charcoal by coke in the small furnaces now employed, except for special brands. The same also applies to the production of puddled iron, foreign crude iron being usually preferred. Very little ingot-steel is made, other Italian or imported ingots being found superior. Should, however, the supply of old iron fail, as is probable, the sole means of replacing this material is by the reverberatory-furnace process, which therefore merits attention.

The chief centres of iron-manufacture from imported material are near Lecco and in the Val Sabbia, but since the raising of the import duty on broken pig and ingot-steel inferior crude iron has had to be used.

Owing to the position and condition of the local mines and blast-furnaces, it seems impossible for Lombardy to compete in price with Tuscany and foreign countries, most of the iron now produced being from old stocks of ore acquired below cost. An exception might be afforded in the case of special foundry-iron which could be prepared at Val Seriana, Val di Scalve and Val Camonica with suitable plant. C. S.

DRY-COAL COKING PLANT.

Berg- und Hüttenmännischer Verein in Mährisch-Ostrau: Excursions-bericht. By — KOHOUT *and* — JICÍNSKY. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen, Vereins Mittheilungen*, 1899, *pages* 55-57.

A modified form of the Otto-Hoffmann coke-oven has been adapted by Mr. J. Plzák at Dombrau, Austrian Silesia, for coking washed slack coal, which cannot be coked in an ordinary oven. He has erected two batteries of 30 ovens, each 32·81 feet (10 metres) long, 38·58 inches (980 millimetres) high, and 39·37 inches (1,000 millimetres) wide, taking a load of 7½ tons, which is burnt for 48 hours and produces 5 tons of coke. It will be noted that these ovens are wider and lower than the ordinary coke-oven. The small coal is classed by a drum-screen into seven sizes, which are cleaned by Baum jigging-machines.* All sizes passing over a mesh-diameter of 0·79 inch (20 millimetres) are sold as nut coal, while the smaller sizes are lifted by centrifugal pumps into storage-hoppers of 600 tons capacity, and are ground in a disintegrator and coked. The waste-gases of the coke-ovens are passed through condensers and yield 3·5 per cent. of tar and 1·2 per cent. of ammonium sulphate, calculated on the weight of coal coked. The waste-gases, in excess of those used in heating the ovens, are applied to the production of steam from 4 water-tube boilers for an electric generating-plant of 600 horsepower. One 30 horsepower motor drives the coke-ram; an 80 horsepower motor, the condensing-plant; a 50 horsepower motor, the boiler-feed; 3 motors, totalling 280 horsepower, the coal-washing machinery; and 3 motors each of 16 horsepower, work the rope-way, 2,800 feet long, a wagon-traverser, and the electric-lighting station. M. W. B.

TIME IN COKE-MAKING.

Time in Coke-Making. By WILLIAM GILBERT IRWIN. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix.*, *page* 256.

Time in coke-making has long been one of the important questions with coke-makers, and for many years the leading operators have been seeking for means to economize in this respect and at the same time to maintain the standard of excellence requisite in an efficient furnace and foundry fuel. But no real progress has ever been made along this line, so far as concerns the bee-hive coke-oven. After describing a number of experiments made by various companies in this direction, and tabulating the results, the writer concludes that the most successful system of the new type seems to be the Semet-Solvay system. By this system, a good quality of coke is obtained in 36

* *Trans. Inst. M.E.*, vol. vii., page 156.

hours, and at the same time all the bye-products are utilized. Apart from the economy in time, the adoption of the bye-product oven is a step towards the abatement of smoke. Also, leaving out the question of increased production through the reduction of time required for coking, the bye-products would for western Pennsylvannia alone reach £2,000,000 ($10,000,000) annually, while at present this is a total loss. Altogether it is not reasonable to hope for any decided results in the reduction of time in coking, until the industry shall have been placed on scientific lines by the general adoption of the bye-product type of coke-oven. X. Y. Z.

THE RICHÉ WOOD-GAS GENERATOR.

Generating Gas from Wood. *By* JAMES M. NEIL. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxx., pages* 281-282, *with* 1 *illustration.*

To miners, smelters, etc., who have difficulty in obtaining coal or coke, the Riché generators are useful, as the gas gives a powerful heat and is suitable for motive power. From a table of analyses submitted by the writer, it appears that wood-gas may now be obtained of a calorific power approaching that of coal-gas. The principle of the Riché generator is based upon the reducing power of carbon; and by its means all the volatile products of wood, peat, etc., are reduced into stable, simple compounds, producing three times as much rich permanent gas as was formerly possible, without the aid of purifiers, the only other product being a saleable charcoal which often pays for the first cost of the wood.

The Riché generator is composed of a kiln of ordinary red-bricks and fire-bricks reinforced by an iron ring. Inside of this masonry are the beds for the retorts, which latter are heated by fire-boxes at the end of the kiln. These fire-boxes are so arranged that the heating of the kiln can be shut off or started at a moment's notice, and the construction is such that any retort may be taken out and replaced without hindering the usual work of the generator. One man looks after a generator of 6 retorts, and on a smaller plant he usually attends to the gas-engine as well. Each retort produces 180 cubic feet of gas; 1 ton of wood produces more than 25,000 cubic feet of gas, and about 400 pounds of wood-charcoal; and a horsepower-hour can, it is claimed, be obtained at a cost of less than ½d. (¼ cent). The gas does not give a flame for illuminating purposes, but when used with an incandescent mantle it gives a light of 50 candle-power with a consumption of 5½ cubic feet of gas per hour. With wood at 12s. 6d. (3 dollars) per ton, and leaving the charcoal out of account, Riché wood-gas costs 7d. (14 cents) per 1,000 cubic feet.

X. Y. Z.

PYRITIC SMELTING AND HOT BLAST.

Pyritic Smelting and Hot Blast. *By* S. E. BRETHERTON. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxx., pages* 760-761.

Pyritic smelting is the utilization of sulphides as both flux and fuel, the metallic bases, excepting copper, uniting with the silica to form a slag, and the copper acting as a collecting agent to gather the precious metals into a copper-matte, the sulphur uniting with the oxygen of the blast to generate heat, just as the carbon from fuel does. The writer discusses some of the problems confronting those who contemplate the erection of a matting-furnace for the reduction of a great variety of ores, and maintains that, in general,

copper-smelting and hot blast are more efficient and less costly than lead-smelting and cold blast. The disadvantages inseparable from a cold blast are especially noted, and it is claimed that the advantages of the hot blast are, speaking generally, improved chemical conditions, economy of fuel, and greater capacity of furnace.

After referring to several inventions designed to heat the air automatically and without cost, the author refers to his own arrangement—the Bretherton hot-blast apparatus. In constructing this apparatus, the principal features required for its success were kept in mind, such as doing away with the back pressure on the blower so that the volume of air would not be minimized; taking the heat from the escaping heat of the hot slag by building an oven round the fore-hearth—the oven having flues passing through it for escaping fumes of the slag; and augmenting the heat acquired in that manner somewhat, by using a set of air-jackets above the water-jackets round the furnace, the air having a continuous passage from the blower to the tuyères. In this way the top of the furnace was kept cool, so as to prevent volatilization.

The first and most important item to consider when heating the air-blast is that it in no way interferes with the regular working of the blower, as the blast passes cold through the blower. All calculations as to the amount of blast required and used can be based on the regular volume handled by the blower, the same as when using cold blast. In this way, the amount of free oxygen sent into the blast-furnace, whether heated or cold, can be calculated, provided there is no obstruction of the free passage of the air through the heating apparatus. It is therefore necessary that the area of the heating-box shall be larger than the inlet where the cold blast enters, so that no back pressure is created. The outlet of this heating-box should be made with nearly double the capacity of the inlet.

By the latest arrangement at Silverton, Colorado, the writer utilizes not only what little heat there is to be saved practically above the feed floor, but also the heat which would otherwise go to waste, through a much needed, large, enclosed matte-settling arrangement. It is the same arrangement as that first started with, excepting that all the heat in that case was obtained from the slag and the wood burned on the settler's surface. With that the fuel was reduced to one-third, and all preliminary roasting dispensed with, where previously it had been necessary to roast two-thirds of the ore and concentrates smelted. X. Y. Z.

THE HANS A. FRASCH ELECTROLYTIC PROCESS FOR EXTRACTING METALS, AS APPLIED TO COPPER-NICKEL MATTE.

The Hans A. Frasch Electrolytic Process for Extracting Metals, as applied to Copper-Nickel Matte. *By* RICHARD P. ROTHWELL. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxx., pages* 272-273.

This process bids fair to revolutionize the present methods of extracting not only copper and nickel from their ores and metallurgical products, but appears adaptable to the winning of silver, mercury, and other metals that have hitherto offered almost insurmountable difficulties to their economical extraction in the wet way.

The process as applied to the Sudbury copper-nickel matte is simplicity itself in idea and arrangement. Briefly outlined, it consists of the electrolysis of a brine-solution in such a manner that while the sodium ions are set free at the cathodes with the immediate formation there of caustic soda, the chlorine ions are liberated in the anode section containing the matte, and

immediately form a chloride solution of the metals present. In this way, brine is electrolysed to form caustic soda at even less expense than with the insoluble anodes in the Castner-Kellner or Rhodin precesses, and at the same time the chlorine, instead of being made into bleach, is directly utilized for the formation of the chlorides of copper, nickel, iron and other metals that are in combination in the matte at the anode poles. In other words, in the ordinary caustic-soda manufacture, to produce it economically requires the combination of the chlorine set free to form the bye-product bleach, while in the present Frasch process the caustic soda itself becomes a bye-product and the chlorine combines with the metals in the matte practically at the instant it is set free, and produces a solution of metallic chlorides that can be directly treated for the contained metals by electrolysis or chemical methods; or, after being electrolysed of half its content of copper (corresponding to the conversion of the cuprous into the cupric salt), it may be used for the lixiviation of the metals in the raw matte: the copper-chloride solution, being in the cupric condition, acts chemically as a solvent for the metals in the matte, and re-forms the electrolyte solution suitable for further electrolysis. Eventually, the metals in the solution are recovered by electrolytic deposition, or, in the case of nickel and cobalt, the nickel is separated from the cobalt as a chemical salt by a method which Mr. Frasch prefers not to disclose at present.

The electrical and chemical principles involved are perfectly sound and under easy control, and the mechanical side of the process calls for very simple treatment. The matte is submitted to a coarse crushing and conveyed to the vats, where it is charged on a layer of carbonaceous material forming the anode section at the bottom. On this layer of matte is placed a thin layer of sand which gives a very satisfactory diaphragm for the separation of the resultant solutions of caustic-soda and the chlorides of the metals. The anode section of the vat is then filled to the sand-layer with a saline or a weak chloride solution from a previous operation, and the balance of the vat is filled with water or with a weak caustic solution. The passing of the two solutions from the reservoirs to and through their respective anode and cathode sections of the vats and thence to receiving-tanks is accomplished mainly by gravity. The subsequent handling of the solid material which remains in the anode section after treatment, consists of the removal of the upper layer of sand, which can be washed and used again, followed by the removal of the leached material, from which perhaps it might prove economical to extract the sulphur.

As a matter of record the following facts may be stated:—The matte under treatment was of this composition: copper, 31·8; nickel, 14·8; iron, 25; and sulphur, 24 per cent. The first solution from the anode section contained, in grammes per litre, copper, 50; nickel, 43; and iron, 26·6. After the removal from this solution by direct electrolytic deposition of one-half the copper-content, a second percolation through the anode sections gave a solution that contained in grammes per litre, copper, 50; nickel, 60; and iron, 35. By a further intermediate removal of the copper from the chloride solution with intermediate percolation through the anode section or sections, the percentage of nickel can be raised to any required degree. In the tests carried out at the works of the Nickel-Copper Company (Hamilton, Ontario), the result obtained fully reached the theoretical quantities; in fact, they somewhat exceeded them, as often occurs in electrolytic work where soluble anodes are employed. It is claimed that the entire cost of the process will be fully met by the value of the caustic soda and other bye-products. X. Y. Z.

COST OF SMELTING AND REFINING.

Notes on Lead Smelting and Gold and Silver Refining: Cost of Smelting and Refining at the Globe Works, Denver, Colorado. By MALVERN W. ILES. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxx., pages* 185-186.

Cost of Hand-roasting per Ton (2,000 pounds) *of Ore.*—In 1888, the cost was about 17s. 10d. (4·28 dollars), after which the cost gradually fell year by year until in 1898 it was 10s. 11d. (2·62 dollars) per ton. These figures may be rather higher than the average, but the roasters were charged in proportion with expenses of general management, office, etc. In viewing the yearly reduction of costs, it must be noted that much was due to improved furnace-construction, and that an important change was also made in the condition of the product. These changes are described, and the experimental results proved that the best condition of product is a semi-fused or sintered state, in which the particles of roasted ore have been compressed by pounding the material which has been drawn into the slag-pots with a heavy iron disc.

Comparative Cost of Hand-roasters and Mechanical Furnaces.—At first, the roasting was done mainly by hand-roasters. Later two Brown-O'Harra mechanical furnaces were used. The comparison of the cost of labour by the two methods shows a gain of 2s. 3d. (54 cents) per ton in favour of the mechanical furnaces. The writer, however, considers the gain a costly one, which is more than off set by the cost of the high-grade fuel required, and the cost of repairs, and thinks that, taking a term of years, the hand-roasting will be cheapest in the end. The costs, by the two methods for each month of 1898 have been taken out, the quantity roasted each month runs from 5,000 to 6,000 tons, and the costs include labour, coal and general expenses. The total average cost per ton for the year is 11s. 5½d. for the hand-roasters and 9s. 2½d. for the mechanical furnaces (2·75 and 2·21 dollars respectively).

Cost of Smelting.—The total cost of smelting is made up of a large number of items, but a great advance has been made in the development of smelting. In 1887, the average cost per ton was 19s. 4½d. (4·64 dollars), and in 1898 it had fallen to 9s. 5d. (2·26 dollars). Some of the changes which made this reduction possible were: Enlargement of area of furnace at tuyeres from 30 by 100 to 42 by 140 inches; height of charge from tuyeres increased from 11 to 16 feet; blast-pressure raised from 1 to 3 or 4 pounds per square inch; and fore-hearth capacity increased from 6 to 128 cubic feet. In 1886, slag settled in pots; in 1899, in furnaces; in 1886, the fuel was charcoal, in 1899, coke; in 1886, 280 pounds of slag were removed per trip by hand, whilst in 1899, from 3,000 to 6,000 pounds were removed per trip by locomotive; in 1886, 200 pounds of matte were removed per trip by hand, and in 1899 ten times the quantity was removed per trip by horsepower.

Cost of Refining by the Parkes Process.—In general, it may be stated that the average cost of refining base bullion varies from 12s. 6d. to 21s. (3 to 5 dollars) per ton. This amount is based on the cost of labour, spelter, coal, coke, supplies, repairs and general expenses. When the additional items of interest, expressage, brokerage, and treatment of bye-products are considered, the total refining cost may be stated approximately as 42s. (10 dollars) per ton of bullion treated. Variations in the cost occur from time to time, and are due to several causes, principally the irregularity of the bullion-supply, and its consequent effect on the work of the plant. The writer concludes by analysing the different items of cost, and pointing out those which offer the most room for improvement. But it is specially remarked that the item of parting and brokerage is the largest of the refinery costs, and that, for obvious reasons, every modern smelting-plant should have a parting-plant under its own control. X. Y. Z.

II.—BAROMETER, THERMOMETER, ETC., READINGS FOR THE YEAR 1899.

By M. WALTON BROWN.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of Glasgow and Kew Observatories, and give some idea of the variations of atmospheric temperature and pressure in the intervening districts in which mining operations are chiefly carried on in this country.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometrical readings at both observatories are reduced to 32° Fahr.

The statistics of fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are also printed upon the diagrams (Plates XX. and XXI.) recording the meteorological observations.

TABLE I.—SUMMARY OF EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1899.

Mines-inspection Districts.	Fatal Accidents.			Non-fatal Accidents.	
	No.	Deaths.	Injured.	No.	Injured.
Durham	2	7	6	5	8
Ireland	0	0	0	0	0
Liverpool	1	2	0	2	4
Manchester	0	0	0	1	1
Midland	0	0	0	5*	4
Newcastle-upon-Tyne ...	2	2	3	9*	12
Scotland, East	5	7	4	31	40
Do. West	8	9	8	27	37
South Wales	2	20	0	28	37
South-Western	0	0	0	2	2
Staffordshire, North ...	0	0	0	2	3
Do. South ...	2	5	3	10	13
Yorkshire	1	2	2	3	7
Totals	23	54	26	125	168

* Including an explosion by which no person was injured.

TABLE II.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1899.

1899.	Colliery.	Mines-inspection Districts.	Deaths.	No. of Persons Injured.
Jan. 9, 8·0 a.m.	Gilbertfield (No. 2 Pit)	Scotland, West ...	1	0
,, 10, 6·45 ,,	Pumpherston (Oil-shale)	Scotland, East ...	1	0
Feb. 17, 6·0 ,,	Walbottle	Newcastle-upon-Tyne	1	2
Mar. 11, 4·0 p.m.	Cadeby Main ...	Yorkshire	2	2
,, 18, 10·30 a.m.	Gartshore (No. 9 Pit)	Scotland, West ...	1	0
April 4, 2·30 ,,	Drumpeller (Nos. 3 and 4 Pits) ...	Do. ...	1	0
May 15, 4·50 ,,	Etherley Grange ...	Durham	1	2
,, 22, 6·0 ,,	Benarty	Scotland, East ...	2	1
,, 24, 1·30 ,,	Woodhall (No. 1 Pit)	Scotland, West ...	1	1
,, 25, 7·40 ,,	Millfield	Staffordshire, South...	4	3
June 9, 2·30 ,,	Ynisgeinon	South Wales ...	1	0
,, 19, 7·0 ,,	Brownhills	Staffordshire, South...	1	0
,, 20, 10·30 ,,	Holytown (No. 5 Pit)	Scotland, West ...	2	5
Aug. 15, 8·30 ,,	Brandon	Durham	6	4
,, 15, 9·30 p.m.	Wester Gartshore ...	Scotland, West ...	1	0
,, 18, 2·0 a.m.	Llest	South Wales ...	19	0
Oct. 10, 11·0 p.m.	Hamilton Palace (No. 1 Pit)	Scotland, West ...	1	2
,, 26, 9·0 ,,	Calderbank (No. 1 Pit) ...	Do. ...	1	0
Nov. 3, 2·0 ,,	Bedlington (A Pit) ..	Newcastle-on-Tyne...	1	1
,, 23, 10·30 a.m.	Point of Ayr	Liverpool	2	0
Dec. 6, 11·0 p.m.	Kinneil	Scotland, East ...	2	0
,, 25, 6·0 a.m.	Longriggend ...	Do. ...	1	0
,, 27, 7·30 ,,	Ingliston (Oil-shale)	Do. ...	1	3
		Totals ...	54	26

TABLE III.—LIST OF NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1899.

1899.	Colliery.	Mines-inspection Districts.	No. of Persons Injured.
Jan. 6, 2·0 p.m....	Llest	South Wales	1
,, 10, 7·15 a.m....	Broxburn (Oil-shale)	Scotland, East ...	1
,, 12, 4·0 p.m....	Camp (No. 1 Pit) ...	Scotland, West ...	2
,, 28, 9·0 a.m....	Gelliceidrim	South Wales	4
Feb. 6, 9·30 ,, ...	Brownhills	Staffordshire, South ...	1
,, 6, 5·0 p.m....	Tyrddcrwen	South Wales	2
,, 8, 12·30 a.m....	Cwrt-y-Bettws ...	Do. ...	1
,, 13, 3·0 p.m....	Granville (No. 2 Pit)	Midland	0
,, 18, 6·0 a.m....	Camerton	Newcastle-upon-Tyne	1
,, 20, 5·45 ,, ...	Glenboig (Fire-clay)	Scotland, East ...	1
,, 23, 1·0 p.m....	Nunnery	Yorkshire	4
,, 25, 7·30 a.m....	Woodilee	Scotland, West ...	1
Mar. 3, 6·0 p.m....	Longriggend	Scotland, East ...	2
,, 8, 12·0 ,, ...	Meiros	South Wales	1
,, 9, 12·0 noon...	Cadder (No. 16 Pit) ...	Scotland, West ..	2
,, 15, 7·15 a.m....	Haughhead	Do.	2
,, 15, 11·0 p.m....	Bridgeness	Scotland, East ...	1
,, 23, 11·30 a.m....	Birchgrove	South Wales	1

TABLE III.—*Continued*

1899.	Colliery.	Mines-Inspection Districts.	No. of Persons Injured.
Mar. 24, 6·0 p.m....	Maypole (Sinking Pit)	Liverpool	2
,, 28, 7·30 a.m...	Carfin (No. 1 Pit) ...	Scotland, West ...	1
April 6, 11·50 p.m....	Llest	South Wales	1
,, 7, 7·30 a.m....	Llest	Do. ...	1
,, 7, 10·0 ,, ...	Bredisholm (No. 6 Pit)	Scotland, West ...	2
,, 12, 10·0 p.m....	Maesteg (No. 9 Pit) ...	South Wales	1
,, 12, 10·0 ,, ...	Newbattle	Scotland, East ...	1
,, 14, 2·40 ,, ...	Roman Camp (Oil-shale)	Do. ...	1
,, 15, 7·15 a.m...	Merthyr Llantwit ...	South Wales	2
,, 17, 2·20 p.m....	Law	Scotland, East ...	1
,, 18. 11·0 a.m....	Glyn	South Wales	2
,, 21, 10·0 ,, ...	Elland Road	Yorkshire	1
,, 24, 3·0 ,, ...	Shilbottle	Newcastle-upon-Tyne	1
,, 24, 4·30 ,, ...	Dinas Isha (No 2 Pit)	South Wales	1
,, 27, 12·30 p.m....	Birchgrove	Do. ...	1
May 4, 8·40 a.m....	Hazlerigg	Newcastle-upon-Tyne	1
,, 8, 9·40 ,, ...	Dumbreck (No. 2 Pit)	Scotland, West ...	1
,, 11, 12·30 p.m...	Blarglachan (No. 2 Pit)	Do. ...	2
,, 15, 4·30 a.m....	Wooley	Durham	1
,, 15, 9·0 p.m....	Kenmuirhill (No. 2 Pit)	Scotland, West ...	1
,, 18, 1·0 ,, ...	Cornsilloch	Scotland, East ...	1
,, 19, 7·30 a.m ...	Cannock Old Coppice	Staffordshire, South ...	1
,, 25, 6·30 ,, ...	Carronhall	Scotland, East .	1
June 2, 4·0	Elled	South Western ...	1
,, 3, 9·30 ,, ...	Walsall Wood	Staffordshire, South ...	1
,, 8, 8·0 p.m....	Holmes (Oil-shale) ...	Scotland East ...	1
,, 11, 10·0 ,, ...	Greenfield (No. 7 Pit)	Scotland, West ...	1
,, 12, 9·30 a.m....	Carfin (No. 3 Pit) ..	Do. ...	1
,, 13, 4·10 p.m. ..	Hodgens	South Wales	2
,, 19, 8·20 a.m....	Shilbottle	Newcastle-upon-Tyne	2
,, 23, 12·30 p.m....	South Rhondda ...	South Wales	1
,, 26, 6·0 a.m. ..	Cawdor	Do. ...	1
,, 27, 2·30 ,, ...	Swanwick	Midland	1
July 5, 10·50 a.m....	Foxfield	Staffordshire, North ...	1
,, 10, 2·30 p.m....	Primrose	South Wales	1
,, 12, 2·0 ,, ...	Belhaven(Meadowhead Pit)...	Scotland, West ...	1
,, 13, 8·0 a.m....	Springhill (No. 4 Pit)	Do. ...	2
,, 19, 9·30 ,, ...	West Cannock ..	Staffordshire, South ...	3
,, 20. 10·0 ,, ...	Darran	South Wales	1
,, 21, 7·30 ,, ...	Llest	Do. ...	1
,, 21, 8·45 ,, ...	Glengarnock (No. 6 Pit)	Scotland, West ...	1
,, 25, 7·0 p.m....	Corrwg Rhondda ..	South Wales	1
,, 26, 2·30 a.m....	Kibblesworth... ...	Newcastle-upon-Tyne	2
Aug. 3, 6·0 p.m....	Cornsilloch	Scotland, East ...	1
,, 8, 2·0 ,, ...	Capel Ifan	South Wales	2
,, 8, 4·0 ,, ...	Motherwell	Scotland, East ...	1
,, 12, 2·0 a.m....	Kilton	Durham	4
,, 12, 8·0 ,, ..	Haughhead	Scotland, West ...	1
,, 13, 9·45 p.m....	Bogleshole (No. 4 Pit)	Do. ...	3
,, 14, 6·30 a.m....	Broxburn (Oil-shale)	Scotland, East ...	1
,, 18, 9·15 p.m...	Ashton Vale	South Western ...	1
,, 19, 8·0 a.m....	Bretby	Midland	1
,, 20, 10·0 p.m....	Pumpherston(Oil-shale)	Scotland, East ...	1
,, 24, 6·30 a.m....	Forkneuk (Oil-shale)	Do. ...	1
,, 28, 5·30 p.m....	Tydraw	South Wales	1
,, 30, 8·30 a.m....	Corby Craigs (No. 4 Pit)	Scotland, West ...	2

TABLE III.—*Continued.*

1899.	Colliery.	Mines-Inspection Districts.	No. of Persons Injured.
Aug. 31, 7·0 a.m....	New Hermand (Oil-shale)	Scotland, East ...	2
Sept. 4, 4·0 p.m....	Meiros	South Wales	1
,, 6, 9·45 ,, ...	Ouston (E Pit) ...	Newcastle-upon-Tyne	0
,, 7, 7·0 a.m. ..	Dalmeny (Oil-shale)...	Scotland, East ...	4
,, 8, 11·0 ,, ...	Wood Farm	Staffordshire, South ...	1
,, 15, 12·40 p.m. ..	Highhouse (No. 1 Pit)	Scotland, West ...	2
,, 16, 6·0 a.m....	Blairhall	Scotland, East ...	1
,, 18, 5·45 ,, ...	Murdostoun	Do.	1
,, 19, 3·30 ,, ...	Dalmeny (Oil-shale)...	Do.	1
,, 25, 6·0 ,, ...	Arniston	Do.	1
,, 29, 9·0 ,, ...	Backworth (Algernon Pit)	Newcastle-upon-Tyne	2
Oct. 3, 6·0 ,, ...	Clough Foot (Mountain-mine) ...	Manchester	1
,, 4, 11·30 ,, ...	Pumpherston (Oil-shale)	Scotland, East ...	1
,, 6, 5·30 ,, ..	Lumpsey	Durham	1
,, 7, 8·30 p.m...	Deckra (No. 1 Pit) ...	Scotland, West ...	1
,, 12, 12·30 a.m....	Allanton	Scotland, East ...	1
,, 20, 1·30 p.m....	Horseley	Staffordshire, South ...	1
,, 24, 6·0 ,, ...	Tyrdderwen	South Wales	1
,, 25, 7·30 a.m....	Knowle	Staffordshire, South ...	1
,, 26, 6·15 p.m....	Allanton	Scotland, East ...	1
Nov. 1, 11·0 a.m....	Gilbertfield (No. 1 Pit)	Scotland, West ...	1
,, 3, 11·20 ,, ...	Camp (No. 1 Pit) ...	Do.	1
,, 3, 12·0 noon...	Peel (No. 3 Pit) ...	Midland	1
,, 4, 6·0 a.m....	Kenmuirhill (No. 2 Pit)	Scotland, West ...	1
,, 10, 8·30 ,, ...	Manor	Yorkshire	2
,, 13, 8·0 ,, ...	Wellshot (No. 1 Pit)...	Scotland, West ...	1
,, 20, 0·30 ,, ...	Kenmuirhill (No. 2 Pit)	Do. ...	1
,, 20, 3·0 ,, ...	Barblues	Scotland, East ...	1
,, 21, 5·0 ,, ...	Drummuir (No. 3 Pit)	Scotland, West ...	1
,, 23, 5·30 ,, ...	Walsall Wood... ...	Staffordshire, South ...	1
,, 23, 9·0 ,, ...	Point of Ayr	Liverpool	2
,, 23, 1·30 p.m....	Limefield (Oil-shale)	Scotland, East ...	1
,, 23, 3·45 ,, ...	Velinfran	South Wales	1
,, 24, 7·20 a.m....	Foxfield	Staffordshire, North ..	2
,, 29, 0·45 ,, ...	Glencraig	Scotland, East ...	2
,, 30, 11·30 ,, ...	Saltwells	Staffordshire, South ...	2
Dec. 2, 9·30 ,, ..	Blackwell (A Pit) ...	Midland	1
,, 11, 4·30 p.m....	Bradley	Staffordshire, South ...	1
,, 13, 5·20 a.m....	Seafield (Oil-shale) ...	Scotland, East ...	1
,, 13, 12·0 noon...	Roman Camp (Oil-shale)	Do. ...	1
,, 13, 6·30 p.m....	Birchrock	South Wales	1
,, 14, 8·0 a.m....	Birchrock	Do. ...	1
,, 17, 10·15 p.m....	Dunnikier	Scotland, East ...	1
,, 19, 1·45 ,, ...	Walkinshaw (No. 2 Pit)	Scotland, West ..	1
,, 19, 6·45 p.m....	Merthyr Llantwit ...	South Wales	2
,, 26, 7·0 a.m....	Swalwell	Newcastle-upon-Tyne	1
,, 28, 2·30 p.m....	Polbeth (Oil-shale) ...	Scotland, East ...	4
,, 28, 8·5 ,, ...	Langley Park... ..	Durham	1
,, 28, 9·30 ,, ...	Byers Green	Do. ...	1
,, 29, 6·45 a.m....	Cramlington (Wrightson Pit)	Newcastle-upon-Tyne	2
,, 29, 7·30 ,, ...	Rosehall (No. 7 Pit) ...	Scotland, West ...	1
		Total	168

TABLE IV.—BAROMETER, THERMOMETER, ETC.. READINGS, 1899.

JANUARY, 1899.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.
1	29·259	29·261	29·036	28·999	42·2	32·6	WSW	1	29·152	29·062	28·848	28·695	38·1	33·2	ESE
2	28·932	28·910	29·045	29·155	41·9	36·0	W	2	28·562	28·600	28·884	29·210	39·5	33·5	S
3	29·454	29·757	29·928	29·942	43·4	39·8	NNW	3	29·497	29·665	29·638	29·525	45·6	34·9	S
4	29·930	29·997	29·989	30·037	52·1	41·3	SW	4	29·696	29·652	29·588	29·757	48·8	39·4	E
5	30·188	30·301	30·361	30·400	49·2	29·9	W	5	29·901	30·017	30·149	30·243	42·1	35·4	WSW
6	30·339	30·258	30·153	30·043	46·2	28·8	S	6	30·156	29·858	29·895	29·927	43·3	34·1	S
7	29·894	29·852	29·761	29·749	50·1	43·2	SW	7	29·377	29·797	29·664	29·624	38·1	29·6	E
8	29·732	29·753	29·773	29·691	53·2	45·3	S	8	29·561	29·558	29·485	29·417	47·4	37·6	E
9	29·605	29·567	29·445	29·375	51·9	44·9	S	9	29·329	29·340	29·221	29·117	49·8	43·4	S
10	29·305	29·262	29·364	29·375	50·7	41·9	SSW	10	29·000	29·005	29·047	29·136	45·0	38·0	SSW
11	29·453	29·553	29·396	29·660	44·0	36·9	S	11	29·167	29·183	29·177	29·251	40·4	34·3	S
12	29·607	29·310	29·167	29·439	54·2	38·2	SW	12	29·150	28·699	28·602	29·175	41·8	33·4	WSW
13	29·740	29·772	29·476	29·738	54·8	39·8	S	13	29·402	29·407	29·373	29·443	40·9	35·2	W
14	29·836	29·917	29·970	30·037	45·7	36·0	W	14	29·516	29·638	29·690	29·691	43·8	37·2	WSW
15	30·025	29·967	29·663	29·645	54·1	35·9	S	15	29·686	29·587	29·390	29·178	42·9	39·1	E
16	29·510	29·471	29·341	29·393	53·1	43·1	SW	16	29·052	28·952	29·007	29·395	47·1	32·5	W
17	29·692	30·008	30·043	29·853	43·5	34·3	W	17	29·640	29·793	29·811	29·717	36·3	31·9	W
18	29·777	29·829	29·795	29·762	52·3	41·5	SW	18	29·543	29·366	29·192	29·147	50·5	31·3	NE
19	29·653	29·594	29·622	29·675	53·1	44·7	SW	19	29·107	29·151	29·198	29·154	50·4	41·9	WSW
20	29·722	29·737	29·637	29·557	51·5	44·1	SSW	20	29·105	29·319	29·256	29·156	44·8	40·3	WSW
21	29·473	29·456	29·395	29·326	55·4	50·6	SSW	21	28·950	28·922	28·934	28·914	47·8	40·1	SW
22	29·325	29·399	29·460	29·547	52·9	44·6	SW	22	28·840	28·948	29·161	29·453	46·7	37·1	SSW
23	29·594	29·757	29·972	30·169	45·1	38·0	N	23	29·720	29·919	30·048	30·211	38·1	32·1	NW
24	30·247	30·372	30·418	30·502	41·8	32·9	N	24	30·274	30·370	30·421	30·488	34·0	27·4	E
25	30·537	30·619	30·624	30·646	38·3	30·1	NE	25	30·521	30·584	30·580	30·631	37·1	25·6	SSE
26	30·635	30·633	30·570	30·538	41·1	31·6	ENE	26	30·643	30·665	30·631	30·612	37·1	27·7	SSE
27	30·452	30·432	30·364	30·350	41·3	32·9	NE	27	30·560	30·547	30·460	30·439	30·1	22·1	SSW
28	30·297	30·285	30·190	30·154	39·8	31·3	NNE	28	30·403	30·390	30·315	30·247	32·1	22·5	WNW
29	30·078	30·034	29·945	29·920	41·3	37·3	NNE	29	30·187	30·155	30·099	30·078	39·4	28·4	WSW
30	29·887	29·901	29·669	29·870	43·0	36·3	NE	30	30·045	30·057	29·962	29·946	40·1	33·3	W
31	29·779	29·710	29·606	29·559	38·9	32·1	NE	31	29·819	29·719	29·596	29·520	38·2	33·1	NW

FEBRUARY, 1899.

1	29·498	29·462	29·417	29·423	40·1	31·9	W	1	29·497	29·504	29·501	29·537	39·5	32·7	NNE
2	29·417	29·481	29·539	29·650	39·4	29·1	N	2	29·551	29·616	29·649	29·724	38·7	30·9	NNW
3	29·728	29·833	29·860	29·955	38·8	26·0	NNW	3	29·757	29·808	29·834	29·873	37·1	31·3	N
4	29·977	29·962	29·868	29·739	38·9	23·0	S	4	29·851	29·814	29·692	29·628	35·3	26·1	ENE
5	29·531	29·469	29·651	29·776	38·3	35·3	N	5	29·549	29·616	29·708	29·780	37·0	30·9	E
6	29·760	29·759	29·689	29·625	39·6	35·8	E	6	29·732	29·718	29·656	29·567	36·1	30·4	E
7	29·563	29·476	29·475	29·488	53·3	37·7	SSW	7	29·389	29·251	29·156	29·170	42·8	31·3	ENE
8	29·414	29·459	29·324	29·326	53·1	48·0	S	8	29·068	29·060	28·964	28·868	47·9	39·6	SSW
9	29·389	29·499	29·416	29·432	57·0	48·0	S	9	28·852	29·099	28·976	28·821	50·4	37·9	SW
10	29·464	29·483	29·514	29·606	62·3	50·3	SSW	10	29·029	29·056	28·950	29·040	50·3	43·1	ESE
11	29·614	29·571	29·361	29·278	54·0	48·6	S	11	29·084	29·164	29·050	28·856	50·4	46·4	SSW
12	29·247	29·238	29·325	29·409	49·4	43·8	SSW	12	28·836	28·965	28·969	29·006	48·7	41·3	WSW
13	29·340	29·240	29·198	29·288	53·6	42·0	S	13	29·020	28·954	29·701	28·918	48·1	38·8	ESE
14	29·417	29·549	29·591	29·648	51·2	44·1	SSW	14	28·859	29·055	29·233	29·330	46·1	37·4	NW
15	29·690	29·816	29·801	29·733	51·4	42·4	SSW	15	29·399	29·507	29·602	29·635	45·6	38·9	SW
16	29·747	29·910	22·961	30·012	49·4	38·0	WSW	16	29·620	29·620	29·623	29·693	46·5	36·3	S
17	30·007	30·018	29·992	30·042	55·3	34·9	S	17	29·715	29·760	29·825	29·909	49·0	44·0	SSW
18	30·022	30·042	30·023	30·075	49·0	37·4	SE	18	29·900	29·898	29·916	29·983	48·1	42·7	NE
19	30·103	30·165	30·150	30·179	52·3	38·1	SE	19	30·016	30·120	30·188	30·268	44·1	40·2	E
20	30·181	30·186	30·164	30·213	46·9	44·0	E	20	30·294	30·322	30·276	30·288	42·8	31·9	E
21	30·244	30·294	30·277	30·306	45·3	37·8	E	21	30·260	30·294	30·272	30·284	49·1	39·3	SE
22	30·307	30·344	30·302	30·303	48·8	34·4	E	22	30·272	30·270	30·202	30·221	44·2	32·3	E
23	30·251	30·259	30·220	30·263	52·2	33·2	ESE	23	30·200	30·157	30·115	30·163	45·5	30·4	N
24	30·259	30·285	30·243	30·282	51·9	26·0	SE	24	30·188	30·230	30·209	30·225	43·6	35·1	NE
25	30·282	30·325	30·324	30·347	43·1	30·6	E	25	30·223	30·261	30·273	30·297	41·3	33·3	ENE
26	30·341	30·357	30·331	30·396	42·4	27·3	E	26	30·303	30·320	30·301	30·338	36·5	25·4	NNE
27	30·419	30·507	30·520	30·595	31·7	23·1	ENE	27	30·363	30·411	30·412	30·445	42·7	26·1	W
28	30·630	30·681	30·629	30·634	44·7	21·9	ENE	28	30·449	30·448	30·429	30·442	44·9	35·3	WSW

MARCH, 1899.

KEW.								GLASGOW.							
	Barometer.				Temperature.				Barometer.				Temperature.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.
1	30·618	30·648	30·570	30·580	53·7	29·8	WSW	1	30·443	30·472	30·399	30·332	50·4	44·4	WSW
2	30·504	30·480	30·376	30·360	48·2	31·1	NW	2	30·250	30·229	30·218	30·161	49·8	45·3	WSW
3	30·269	30·189	29·993	29·921	48·9	29·6	W	3	30·008	29·892	29·778	29·760	48·3	41·0	W
4	29·863	29·853	29·847	29·991	47·9	31·8	NW	4	29·789	29·907	29·964	30·075	41·9	34·1	N
5	30·094	30·213	30·199	30·218	41·0	29·3	ENE	5	30·080	30·090	29·978	29·917	43·4	32·2	SW
6	30·139	30·059	29·876	29·763	44·2	26·5	S	6	29·755	29·627	29·505	29·452	43·9	37·7	SW
7	29·660	29·686	29·658	29·698	48·3	25·3	SW	7	29·376	29·385	29·366	29·387	47·1	38·2	SW
8	29·621	29·578	29·397	29·194	49·2	34·9	SW	8	29·353	29·243	29·038	28·842	43·6	36·1	SW
9	28·985	29·093	29·222	29·472	48·7	35·9	W	9	28·809	28·922	29·115	29·334	42·3	34·9	WNW
10	29·633	29·847	29·981	30·127	52·3	33·3	SW	10	29·523	29·660	29·675	29·786	49·1	36·3	WSW
11	30·206	30·293	30·290	30·325	53·1	36·0	WSW	11	29·863	29·935	29·962	29·963	50·1	47·9	WSW
12	30·356	30·440	30·465	30·530	56·1	42·3	N	12	30·143	30·335	30·385	30·421	50·5	43·1	NW
13	30·543	30·576	30·496	30·523	52·1	34·7	E	13	30·402	30·396	30·381	30·412	50·3	40·8	WSW
14	30·516	30·534	30·448	30·451	43·1	31·2	E	14	30·404	30·422	30·380	30·385	50·1	45·3	WNW
15	30·441	30·447	30·364	30·398	50·9	29·2	E	15	30·364	30·396	30·339	30·356	49·9	43·8	W
16	30·392	30·439	30·403	30·421	44·1	29·8	E	16	30·358	30·403	30·347	30·355	52·3	35·2	NW
17	30·396	30·387	30·269	30·174	43·2	32·4	E	17	30·315	30·287	30·177	30·161	58·4	32·1	W
18	30·056	30·126	30·116	30·165	45·0	29·7	NE	18	30·253	30·297	30·277	30·285	47·3	35·1	ENE
19	30·126	30·085	29·942	29·853	40·7	29·2	N	19	30·228	30·093	29·942	29·938	41·9	29·0	NW
20	29·795	29·761	29·738	29·824	40·1	27·3	NNW	20	29·867	29·864	29·829	29·826	38·1	28·2	NE
21	29·820	29·776	29·633	29·634	36·8	22·5	SSW	21	29·743	29·705	29·672	29·710	38·3	27·3	NNE
22	29·641	29·672	29·642	29·728	40·2	23·9	NW	22	29·712	29·734	29·726	29·793	35·9	26·3	N
23	29·732	29·755	29·774	29·912	37·3	24·1	NW	23	29·842	29·901	29·892	29·975	39·1	25·9	N
24	29·931	30·014	30·084	30·197	41·3	24·7	N	24	29·982	29·992	29·981	30·010	39·6	24·1	WNW
25	30·226	30·215	30·121	30·026	45·4	24·4	SW	25	29·944	29·811	29·636	29·658	35·9	31·6	E
26	29·957	30·029	30·023	30·065	53·8	41·1	W	26	29·738	29·814	29·834	29·824	37·1	33·9	E
27	30·010	29·959	29·902	29·987	55·1	34·8	SW	27	29·672	29·590	29·602	29·554	52·4	35·4	W
28	30·013	30·004	29·913	29·818	54·9	44·2	SW	28	29·552	29·512	29·291	29·078	49·8	41·1	SSW
29	29·901	29·917	30·026	30·130	57·9	46·0	W	29	29·209	29·513	29·732	29·833	51·6	45·6	W
30	30·164	30·226	30·228	30·282	57·7	44·2	WNW	30	29·930	30·157	30·216	30·217	47·1	41·3	ESE
31	30·233	30·141	30·070	30·104	59·8	43·7	WSW	31	30·097	29·980	29·927	29·900	42·2	34·0	ENE

APRIL, 1899.

1	30·093	30·111	30·053	30·083	63·8	48·4	SSW	1	29·861	29·845	29·853	29·898	51·6	41·8	W
2	30·076	30·096	30·042	30·032	56·8	48·0	SW	2	29·924	29·937	29·892	29·890	50·3	45·1	S
3	30·021	30·079	30·044	30·131	60·5	46·1	W	3	29·823	29·810	29·862	29·892	52·9	44·2	WSW
4	30·141	30·114	29·987	30·032	55·2	45·7	SW	4	29·743	29·609	29·574	29·545	52·9	45·1	W
5	30·109	30·204	30·151	30·048	58·6	42·8	WSW	5	29·659	29·791	29·667	29·738	48·2	39·8	WSW
6	30·004	30·076	29·922	29·650	58·2	48·4	SW	6	29·806	29·825	29·615	29·201	48·4	38·1	WSW
7	29·365	30·139	29·291	29·546	52·1	44·6	W	7	29·021	29·171	29·484	29·524	45·9	39·3	N
8	29·601	29·551	29·590	29·785	47·2	39·2	NW	8	29·435	29·513	29·623	29·759	47·3	34·4	WNW
9	29·871	29·917	29·830	29·688	52·0	35·1	W	9	29·762	29·717	29·591	29·502	46·3	37·2	WSW
10	29·581	29·585	29·552	29·624	59·3	42·1	W	10	29·415	29·519	29·533	29·634	47·7	37·1	NNE
11	29·624	29·712	29·766	29·863	47·3	35·6	NNW	11	29·690	29·778	29·771	29·797	46·3	35·0	NNW
12	29·819	29·800	29·677	29·557	52·0	33·3	SW	12	29·715	29·596	29·405	29·235	46·4	32·2	SW
13	29·308	29·136	28·882	28·873	50·9	38·6	S	13	29·063	28·977	28·953	29·051	46·1	38·9	ESE
14	28·864	28·958	29·030	29·124	48·2	41·5	W	14	29·129	29·239	29·305	29·381	45·5	40·1	E
15	29·175	29·248	29·284	29·402	51·6	41·0	WSW	15	29·400	29·434	29·479	29·581	45·3	38·9	NE
16	29·478	29·608	29·688	29·804	47·1	39·4	NNW	16	29·633	29·713	29·744	29·791	47·1	33·3	NE
17	29·850	29·928	29·899	29·966	52·1	34·0	SW	17	29·778	29·808	29·805	29·877	46·1	30·2	NW
18	29·978	30·051	30·051	30·131	51·3	32·2	N	18	29·904	29·937	29·878	29·793	46·1	31·2	WSW
19	30·139	30·167	30·100	30·116	58·0	32·7	W	19	29·753	29·833	29·902	29·962	45·7	39·9	WSW
20	30·111	30·102	30·023	30·020	58·2	36·0	WSW	20	29·974	29·991	29·996	30·019	47·2	38·6	NE
21	29·950	29·898	29·831	29·947	47·4	40·4	SE	21	29·972	29·930	29·929	30·058	50·2	32·1	NNW
22	30·081	30·209	30·247	30·289	48·2	35·0	N	22	30·112	30·158	30·148	30·143	45·6	34·4	WNW
23	30·269	30·238	30·139	30·052	52·7	41·8	S	23	30·076	29·994	29·862	29·690	50·2	40·3	S
24	29·906	29·800	29·635	29·541	53·0	46·9	S	24	29·610	29·550	29·431	29·360	57·4	43·1	SW
25	29·497	29·487	29·496	29·418	55·4	44·1	W	25	29·276	29·316	29·288	29·358	53·2	42·1	WSW
26	29·369	29·572	29·687	29·790	54·4	44·0	NW	26	29·448	29·566	29·684	29·789	59·9	44·5	NNE
27	29·857	29·929	29·896	29·915	61·8	42·6	WNW	27	29·811	29·806	29·789	29·709	59·2	43·4	SW
28	29·868	29·859	29·802	29·784	60·8	47·9	SW	28	29·645	29·608	29·558	29·517	56·2	45·2	SSW
29	29·699	29·653	29·602	29·694	59·2	50·7	SW	29	29·430	29·479	29·653	29·846	51·4	38·3	ENE
30	29·885	30·092	30·174	30·243	52·3	39·0	N	30	29·978	30·084	30·099	30·108	50·0	33·4	E

MAY, 1899.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.
1	30·216	30·166	30·037	29·931	55·2	38·8	S	1	30·023	29·870	29·786	29·805	44·3	34·7	E
2	29·862	29·865	29·864	29·887	60·2	47·1	N	2	29·850	29·903	29·955	30·028	48·1	41·3	E
3	29·909	30·012	30·047	30·156	53·1	38·9	NE	3	30·064	30·130	30·162	30·250	50·9	37·7	E
4	30·180	30·238	30·246	30·331	51·6	34·8	NNE	4	30·270	30·312	30·330	30·374	49·7	34·4	ESE
5	30·341	30·385	30·347	30·397	54·0	35·0	N	5	30·385	30·425	30·400	30·471	52·9	34·2	E
6	30·401	30·390	30·335	30·367	56·1	36·1	ENE	6	30·484	30·481	30·437	30·453	55·9	36·3	E
7	30·351	30·305	30·218	30·205	60·6	38·0	NE	7	30·455	30·434	30·350	30·343	58·4	37·4	E
8	30·135	30·066	29·937	29·914	61·4	42·9	NE	8	30·315	30·245	30·123	30·114	61·1	39·0	NE
9	29·853	29·831	29·811	29·852	61·3	44·3	SW	9	30·044	30·013	29·934	29·955	57·1	42·2	E
10	29·860	29·882	29·848	29·892	62·1	41·3	W	10	29·905	29·891	29·885	29·913	57·1	42·3	E
11	29·879	29·902	29·844	29·897	66·3	40·5	NW	11	29·907	29·926	29·927	29·979	60·5	46·3	E
12	29·905	29·918	29·863	29·878	63·2	47·8	S	12	29·971	29·980	29·921	29·909	54·2	45·1	E
13	29·819	29·800	29·721	29·712	61·7	46·7	S	13	29·819	29·762	29·661	29·585	47·5	42·6	E
14	29·642	29·574	29·497	29·474	61·5	49·2	SW	14	29·481	29·441	29·402	29·408	53·6	41·1	SW
15	29·377	29·376	29·399	29·467	60·6	48·2	SSW	15	29·356	29·314	29·253	29·218	53·9	40·1	E
16	29·492	29·610	29·719	29·808	59·7	48·2	WSW	16	29·210	29·257	29·291	29·329	54·3	43·1	WSW
17	29·651	29·808	29·887	29·937	60·3	49·1	SW	17	29·310	29·335	29·507	29·597	52·6	44·9	WSW
18	29·901	29·875	29·779	29·870	68·6	50·1	S	18	29·613	29·527	29·331	29·598	50·3	43·7	E
19	29·979	30·004	29·901	29·755	62·7	47·4	SSW	19	29·710	29·747	29·622	29·459	53·4	43·1	WSW
20	29·698	29·680	29·743	29·844	62·1	53·8	WSW	20	29·406	29·514	29·675	29·833	52·4	46·3	E
21	29·870	29·921	29·950	29·942	59·8	50·0	N	21	29·891	29·952	29·969	30·001	49·3	42·2	E
22	29·912	29·976	29·983	29·997	56·1	46·9	E	22	29·995	29·989	29·969	29·943	46·0	39·2	E
23	29·976	29·965	29·867	29·837	63·3	45·5	SW	23	29·873	29·839	29·737	29·712	50·9	39·1	ENE
24	29·742	29·662	29·569	29·597	61·1	51·0	SW	24	29·663	29·721	29·788	29·890	45·7	42·1	E
25	29·687	29·867	29·954	30·034	51·7	40·7	N	25	29·948	30·004	30·037	30·084	48·1	39·8	E
26	30·053	30·098	30·117	30·181	50·1	37·1	N	26	30·104	30·132	30·145	30·208	52·3	41·1	WSW
27	30·223	30·285	30·311	30·387	52·3	36·3	N	27	30·264	30·304	30·310	30·381	58·9	39·4	WNW
28	30·419	30·446	30·424	30·436	58·7	37·7	NE	28	30·414	30·428	30·393	30·392	62·9	38·0	NW
29	30·423	30·408	30·349	30·365	62·2	38·2	N	29	30·380	30·350	30·299	30·274	64·4	42·9	NW
30	30·362	30·378	30·308	30·341	68·6	38·0	S	30	30·236	30·214	30·187	30·198	63·2	47·9	WSW
31	30·336	30·333	30·273	30·277	71·3	41·9	E	31	30·197	30·213	30·193	30·187	68·1	48·5	W

JUNE, 1899.

1	30·251	30·212	30·129	30·111	76·0	46·7	S	1	30·167	30·127	30·034	29·964	72·2	47·9	SSW
2	30·073	30·072	30·058	30·126	78·6	54·6	SW	2	29·867	29·878	30·010	30·091	65·1	49·1	WSW
3	30·158	30·179	30·125	30·163	74·0	50·9	N	3	30·089	30·091	30·072	30·070	59·3	44·7	SW
4	30·180	30·194	30·158	30·215	79·3	52·3	SW	4	30·087	30·114	30·123	30·169	67·1	52·8	W
5	30·217	30·246	30·212	30·245	80·6	52·2	W	5	30·160	30·201	30·217	30·248	65·5	55·0	W
6	30·246	30·263	30·201	30·254	77·9	53·3	S	6	30·240	30·253	30·246	30·267	72·1	51·1	WNW
7	30·267	30·272	30·248	30·350	75·0	52·4	E	7	30·304	30·319	30·332	30·412	70·5	51·9	E
8	30·370	30·406	30·350	30·384	61·3	49·7	N	8	30·438	30·452	30·402	30·414	67·7	50·4	E
9	30·377	30·385	30·331	30·321	62·3	48·5	NNE	9	30·400	30·368	30·303	30·329	75·9	48·3	W
10	30·306	30·300	30·233	30·251	66·6	50·5	NNE	10	30·301	30·241	30·197	30·213	76·0	49·1	WNW
11	30·237	30·244	30·208	30·194	64·4	47·8	ESE	11	30·189	30·188	30·166	30·185	74·9	55·5	W
12	30·175	30·135	30·040	30·027	75·1	46·8	NNW	12	30·163	30·109	30·037	30·075	77·6	50·1	NW
13	30·021	30·098	30·085	30·083	58·3	48·3	NNE	13	30·118	30·151	30·102	30·094	70·3	54·1	E
14	30·054	30·066	30·041	30·076	58·5	42·6	NNE	14	30·071	30·045	30·016	30·038	76·1	47·1	NE
15	30·084	30·110	30·067	30·068	70·1	42·6	N	15	30·046	30·046	30·022	30·052	75·4	48·4	E
16	30·047	30·051	29·991	30·031	73·9	44·6	NNE	16	30·061	30·048	30·031	30·037	73·8	51·4	W
17	30·017	30·007	29·927	29·925	74·7	46·6	ESE	17	30·003	29·950	29·835	29·763	71·4	52·3	NNW
18	29·866	29·792	29·725	29·689	70·0	48·5	SW	18	29·681	29·615	29·583	29·580	63·3	52·2	S
19	29·649	29·646	29·555	29·475	67·3	51·4	N	19	29·531	29·519	29·499	29·515	60·4	49·6	W
20	29·362	29·359	29·355	29·389	70·7	55·6	SSW	20	29·479	29·452	29·420	29·423	57·1	47·9	E
21	29·424	29·512	29·566	29·624	72·0	55·3	S	21	29·471	29·547	29·588	29·677	61·4	54·5	E
22	29·617	29·630	29·663	29·745	66·6	55·6	N	22	29·709	29·751	29·782	29·828	60·5	55·2	E
23	29·751	29·832	29·881	29·959	64·7	54·8	N	23	29·840	29·869	29·899	29·937	58·9	52·9	WSE
24	29·980	30·020	30·027	30·119	69·2	53·0	NW	24	29·966	29·990	30·030	30·067	61·8	51·9	NW
25	30·125	30·166	30·149	30·152	65·3	51·4	WNW	25	30·051	30·037	30·022	30·024	59·8	49·2	WSW
26	30·157	30·194	30·178	30·244	79·1	59·1	WNW	26	30·017	30·080	30·153	30·204	65·5	55·4	WNW
27	30·269	30·281	30·248	30·212	69·0	55·1	E	27	30·232	30·231	30·167	30·097	62·5	46·4	SE
28	30·120	29·996	29·848	29·782	77·4	53·1	SE	28	29·997	29·881	29·749	29·678	59·5	54·9	SE
29	29·760	29·800	29·799	29·891	72·0	56·6	W	29	29·689	29·723	29·762	29·820	62·3	52·4	WNW
30	29·927	29·945	29·872	29·718	69·6	50·8	W	30	29·813	29·784	29·673	29·542	61·2	46·9	WSW

JULY, 1899.

Date.	KEW. Barometer. 4 A.M.	10 A.M.	4 P.M.	10 P.M.	Temperature. Max	Min.	Direction of wind at noon.	Date.	GLASGOW. Barometer. 4 A.M.	10 A.M.	4 P.M.	10 P.M.	Temperature. Max	Min.	Direction of wind at noon.
1	29·553	29·488	29·505	29·546	65·6	54·8	WSW	1	29·424	29·389	29·364	29·359	57·1	50·5	ENE
2	29·532	29·564	29·640	29·701	62·5	52·8	W	2	29·346	29·407	29·514	29·649	59·5	52·1	NW
3	29·751	29·856	29·897	29·979	63·4	54·3	NW	3	29·741	29·824	29·919	30·011	65·5	52·9	NW
4	30·006	30·057	30·074	30·140	66·6	54·8	NW	4	30·036	30·063	30·067	30·105	67·0	49·1	W
5	30·172	30·209	30·183	30·200	74·0	50·4	NW	5	30·112	30·134	30·128	30·155	72·0	52·9	WSW
6	30·192	30·207	30·181	30·217	76·3	57·3	NNW	6	30·164	30·164	30·154	30·170	71·3	53·6	WSW
7	30·218	30·224	30·185	30·195	79·0	58·0	WNW	7	30·151	30·154	30·126	30·121	69·1	58·9	WSW
8	30·175	30·175	30·127	30·126	76·8	60·0	NW	8	30·075	30·078	30·056	30·030	64·6	55·8	WNW
9	30·117	30·107	30·046	30·053	78·1	57·2	W	9	29·926	29·857	29·814	29·790	65·7	53·4	SW
10	30·036	30·038	29·995	30·003	74·8	60·0	SW	10	29·826	29·847	29·838	29·846	66·4	52·6	W
11	29·953	29·903	29·834	29·811	82·8	60·7	SSW	11	29·836	29·818	29·793	29·788	58·2	52·4	NNE
12	29·749	29·743	29·770	29·842	77·0	60·6	SW	12	29·757	29·738	29·701	29·738	59·8	53·4	E
13	29·860	29·949	29·976	30·059	73·2	55·9	W	13	29·774	29·830	29·818	29·833	66·3	53·5	WSW
14	30·058	30·077	30·081	30·100	71·9	51·7	SSW	14	29·814	29·868	29·902	29·929	68·4	57·1	SSW
15	30·111	30·157	30·146	30·181	71·1	58·9	WSW	15	29·929	29·987	30·015	30·018	64·0	55·4	SW
16	30·167	30·182	30·140	30·143	74·8	56·2	NNE	16	30·055	30·078	30·077	30·092	69·3	55·3	SW
17	30·128	30·105	30·039	30·079	77·9	53·1	S	17	30·072	30·064	30·010	30·015	69·8	56·1	WSW
18	30·066	30·066	30·021	30·027	80·8	55·3	S	18	29·987	29·963	29·942	29·920	69·8	56·2	WSW
19	29·983	29·955	29·892	29·902	84·3	61·2	SSW	19	29·870	29·874	29·885	29·956	68·0	55·2	WNW
20	29·918	29·924	29·890	29·929	85·0	60·0	SSW	20	30·038	30·091	30·096	30·101	63·1	54·3	E
21	29·921	29·986	29·963	30·012	86·4	62·2	W	21	30·062	30·065	30·052	30·075	63·2	54·1	E
22	29·978	29·951	29·878	29·862	81·3	63·2	NE	22	30·053	30·057	30·007	29·978	65·4	56·8	E
23	29·802	29·796	29·774	29·812	68·6	58·9	N	23	29·908	29·895	29·872	29·885	61·4	56·9	E
24	29·832	29·923	29·971	30·078	71·6	58·7	N	24	29·884	29·939	29·979	30·012	64·1	52·8	WNW
25	30·113	30·158	30·143	30·184	77·8	55·0	W	25	29·957	29·923	29·884	29·775	62·6	53·4	WSW
26	30·168	30·177	30·158	30·197	77·9	60·0	WNW	26	29·789	29·979	30·057	30·092	62·9	52·5	WNW
27	30·241	30·294	30·302	30·339	69·9	56·2	N	27	30·091	30·179	30·221	30·231	61·9	52·0	W
28	30·339	30·326	30·270	30·273	73·7	50·7	N	28	30·166	30·197	30·162	30·115	61·6	53·9	W
29	30·241	30·203	30·151	30·189	79·2	53·4	NW	29	30·047	30·051	30·082	30·130	64·1	56·0	WNW
30	30·200	30·233	30·236	30·332	80·3	60·0	N	30	30·151	30·237	30·279	30·333	70·4	53·3	NW
31	30·375	30·422	30·413	30·435	76·3	56·1	E	31	30·354	30·378	30·355	30·347	75·1	52·6	W

AUGUST, 1899.

1	30·408	30·392	30·298	30·281	80·1	54·3	SE
2	30·198	30·144	30·066	30·053	77·2	52·1	E
3	29·992	29·972	29·936	29·967	79·2	61·7	E
4	29·924	29·926	29·912	29·957	77·1	61·5	E
5	29·942	29·919	29·911	29·923	80·0	60·0	E
6	29·947	29·962	29·943	29·958	74·2	62·8	E
7	29·951	29·971	29·960	29·986	71·0	60·9	ESE
8	29·961	29·972	29·952	30·025	71·4	56·3	NE
9	30·020	30·057	30·036	30·128	76·0	54·8	N
10	30·140	30·169	30·148	30·214	75·0	53·4	ENE
11	30·233	30·265	30·220	30·246	74·0	51·1	ENE
12	30·242	30·244	30·208	30·233	74·4	51·9	ENE
13	30·235	30·232	30·166	30·192	74·1	53·7	E
14	30·170	30·157	30·078	30·091	75·8	56·9	SE
15	30·030	29·990	29·909	29·972	86·0	60·7	W
16	30·016	30·105	30·051	30·072	75·6	59·8	N
17	30·065	30·126	30·104	30·138	73·1	56·0	NW
18	30·119	30·158	30·146	30·157	70·2	56·3	N
19	30·161	30·184	30·168	30·188	73·6	61·3	NW
20	30·190	30·220	30·206	30·258	74·1	57·0	NE
21	30·256	30·306	30·252	30·285	72·4	50·8	NE
22	30·284	30·300	30·241	30·258	75·1	48·2	E
23	30·245	30·232	30·159	30·163	78·9	52·8	SE
24	30·118	30·099	30·024	30·028	85·4	60·0	SSE
25	29·992	29·972	29·958	30·043	86·1	58·9	S
26	30·074	30·076	29·973	29·946	80·7	56·3	N
27	29·831	29·769	29·771	29·798	78·3	61·2	W
28	29·787	29·810	29·816	29·870	70·7	56·1	SW
29	29·888	29·898	29·960	29·827	67·6	51·0	SW
30	29·760	29·789	29·776	29·868	72·1	58·0	WSW
31	29·878	29·874	29·779	29·710	*	*	*

1	30·310	30·277	30·219	30·212	76·3	54·4	WSW
2	30·175	30·157	30·094	30·146	76·8	56·2	WNW
3	30·108	30·080	30·038	30·036	64·3	56·2	E
4	30·019	30·026	29·998	30·036	67·4	50·7	E
5	30·033	30·049	30·025	30·038	64·2	53·7	E
6	30·021	30·014	30·007	30·014	59·7	54·4	E
7	30·012	30·058	30·063	30·120	58·3	51·0	E
8	30·113	30·114	30·103	30·135	62·3	50·2	E
9	30·144	30·172	30·149	30·168	63·6	52·1	E
10	30·174	30·191	30·173	30·210	70·1	46·0	SW
11	30·240	30·262	30·233	30·235	73·6	50·9	W
12	30·232	30·232	30·187	30·230	74·6	52·0	W
13	30·242	30·245	30·184	30·175	72·4	56·2	NE
14	30·152	30·120	30·014	29·978	74·6	54·1	ENE
15	29·907	29·876	29·856	29·944	66·3	55·0	WSW
16	29·982	29·971	29·779	29·834	61·1	50·3	WSW
17	29·893	29·960	29·993	30·024	60·7	53·4	WNW
18	30·033	30·059	30·067	30·097	63·1	50·9	W
19	30·110	30·122	30·143	30·165	67·3	52·4	W
20	30·155	30·195	30·197	30·214	73·0	59·4	W
21	30·213	30·238	30·215	30·228	74·9	60·1	WSW
22	30·218	30·231	30·193	30·193	74·9	53·3	WNW
23	30·190	30·170	30·094	30·085	79·4	51·8	E
24	30·032	29·982	29·897	29·897	80·1	57·1	S
25	29·889	29·849	29·788	29·897	73·2	59·2	E
26	29·976	30·015	29·932	29·852	73·2	55·3	W
27	29·728	29·683	29·660	29·684	66·1	56·6	SE
28	29·678	29·686	29·672	29·723	68·2	53·3	WNW
29	29·706	29·688	29·623	29·548	62·3	50·1	S
30	29·514	29·525	29·568	29·641	61·0	55·7	W
31	29·637	29·635	29·589	29·561	62·9	52·9	WSW

* No observation.

SEPTEMBER, 1899

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.		Direction of wind at noon.		BAROMETER.				TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	
1	29·678	29·730	29·713	29·725	71·3	55·4	W	1	29·540	29·573	29·564	29·557	64·6	51·2	WNW
2	29·689	29·726	29·745	29·829	69·1	51·8	W	2	29·523	29·571	29·597	29·692	63·4	53·2	W
3	29·935	30·026	30·035	30·102	73·2	48·2	W	3	29·7o8	29·793	29·831	29·888	61·4	51·3	WSW
4	30·074	30·060	29·969	29·955	78·3	49·2	SSW	4	29·857	29·841	29·745	29·709	67·8	57·2	SW
5	29·889	29·891	29·852	29·920	84·2	56·8	SW	5	29·661	29·785	29·819	29·873	64·1	53·2	NW
6	29·916	29·926	29·873	29·916	72·7	60·3	W	6	29·885	29·913	29·899	29·935	63·1	48·3	NNW
7	29·913	29·941	29·888	29·902	73·0	60·0	E	7	29·925	29·899	29·858	29·852	64·3	52·4	W
8	29·893	29·950	29·974	30·087	74·0	59·9	NW	8	29·914	30·002	30·036	30·071	59·2	46·3	NW
9	30·107	30·148	30·128	30·155	67·6	55·2	NNW	9	30·042	30·032	30·040	30·084	62·1	50·3	NW
10	30·111	30·108	30·118	30·180	63·7	50·0	NW	10	30·078	30·126	30·118	30·134	57·1	49·2	WNW
11	30·202	30·210	30·117	30·086	66·6	44·4	W	11	30·073	30·007	29·993	30·049	63·3	51·2	W
12	30·081	30·126	30·098	30·123	67·9	52·4	N	12	30·037	30·045	30·016	30·021	64·7	48·9	WSW
13	30·083	30·082	30·015	30·012	69·2	46·0	NNE	13	29·969	29·984	29·987	30·013	62·2	49·2	WNW
14	29·986	30·042	29·997	30·044	66·1	50·5	NW	14	29·964	29·938	29·932	30·001	60·1	46·1	W
15	30·047	30·040	29·870	29·709	66·7	48·5	WSW	15	29·965	29·783	29·413	29·398	57·9	42·6	SW
16	29·549	29·555	29·602	29·752	63·5	50·9	WNW	16	29·390	29·525	29·612	29·666	63·2	47·2	N
17	29·783	29·801	29·717	29·751	69·2	50·7	SW	17	29·571	29·492	29·475	29·424	59·1	48·5	WNW
18	29·724	29·703	29·698	29·742	63·9	52·4	WNW	18	29·330	29·335	29·408	29·492	54·1	45·4	WNW
19	29·744	29·730	29·644	29·536	62·7	54·3	W	19	29·420	29·337	29·251	29·273	56·3	47·4	WNW
20	29·547	29·629	29·703	29·794	60·5	47·7	W	20	29·268	29·343	29·438	29 569	53·8	44·8	WNW
21	29·840	29·910	29·829	29·656	61·3	42·6	SSW	21	29·629	29·693	29·615	29·449	54·1	44·1	NW
22	29·467	29·741	29·837	29·942	59·4	48·1	W	22	29·372	29·438	29·510	29·708	52·4	42·2	W
23	29·987	30·006	29·882	29·881	59·0	42·5	W	23	29·680	29·568	29·547	29·658	50·6	43·2	W
24	29·870	29·940	29·926	29·787	60·8	46·1	WNW	24	29·792	29·809	29·601	29·535	51·1	43·3	SW
25	29·751	29·797	29·674	29·564	65·2	53·9	W	25	29·563	29·524	29·228	29·241	55·1	47·3	SW
26	29·585	29·565	29·495	29·529	61·2	49·2	SW	26	29·148	29·029	29·000	29·119	52·0	41·2	WSW
27	29·531	29·509	29·418	29·503	60·3	45·1	S	27	29·165	29·244	29·299	29·426	53·9	44·2	WNW
28	29·545	29·661	29·710	29·790	58·1	40·2	W	28	29·499	29·590	29·600	29·618	51·1	36·1	W
29	29·760	29·721	29·583	29·276	57·7	35·2	S	29	29·611	29·648	29·640	29·677	50·1	37·6	E
30	29·226	29·280	29·338	29·464	55·7	46·0	S	30	29·607	29·491	29·359	29·423	52·4	43·1	NE

OCTOBER, 1899.

1	29·475	29·284	29·108	29·202	62·2	44·3	E	1	29·447	29·477	29·439	29·435	52·5	49·3	E
2	29·186	29·456	29·787	29·981	53·2	43·9	W	2	29·473	29·580	29·684	29·666	53·7	45·5	N
3	30·029	30·024	29·896	29·821	60·5	41·8	SW	3	29·578	29·387	29·338	29·385	55·4	47·5	WSW
4	29·763	29·826	29·862	29·961	57·1	48·3	N	4	29·530	29·704	29·631	29·998	53·5	42·3	W
5	29·984	30·059	30·101	30·166	52·8	43·4	NE	5	30·066	30·135	30·156	30·160	47·9	41·4	NW
6	30·159	30·159	30·112	30·132	54·1	41·9	E	6	30·135	30·128	30·096	30·108	52·4	37·3	W
7	30·139	30·202	30·221	30·301	55·1	36·3	N	7	30·116	30·152	30·189	30·282	53·8	40·3	WSW
8	30·336	30·381	30·323	30·346	55·2	33·4	NNW	8	30·282	30·286	30·220	30·208	54·2	41·7	WSW
9	30·327	30·317	30·235	30·230	57·1	35·0	SE	9	30·167	30·147	30·076	30·044	54·1	45·8	WSW
10	30·228	30·250	30·182	30·170	57·8	33·1	SSE	10	30·009	30·039	29·978	29·910	56·3	52·1	WSW
11	30·086	29·973	29·822	29·750	60·9	35·8	S	11	29·824	29·719	29·570	29·456	57·5	52·7	SW
12	29·639	29·564	29·437	29·562	61·2	45·0	WSW	12	29·326	29·343	29·334	29·410	57·3	41·9	NW
13	29·658	29·807	29·946	30·084	53·3	36·5	NW	13	29·510	29·712	29·820	29·944	46·8	39·8	N
14	30·094	30·141	30·140	30·184	51·3	31·0	N	14	30·046	30·125	30·126	30·161	45·6	33·6	W
15	30·152	30·145	30·033	29·999	52·3	40·8	ENE	15	30·154	30·156	30·051	30·013	49·5	32·4	ESE
16	29·925	29·915	29·872	29·917	56·1	42·0	ENE	16	29·931	29·871	29·780	29·808	54·1	39·3	ESE
17	29·952	30·044	30·087	30·178	58·6	43·9	ENE	17	29·829	29·926	29·995	30·073	59·7	49·7	S
18	30·228	30·310	30·325	30·367	62·0	37·0	E	18	30·142	30·198	30·210	30·240	61·1	54·4	SSW
19	30·366	30·390	30·337	30·364	57·1	37·0	E	19	30·244	30·261	30·218	30·240	61·4	46·1	SW
20	30·345	30·360	30·288	30·329	54·1	34·0	E	20	30·238	30·284	30·282	30·341	56·8	52·9	W
21	30·325	30·390	30·375	30·400	44·1	37·0	E	21	30·356	30·393	30·366	30·363	52·6	42·3	E
22	30·386	30·393	30·323	30·303	52·2	40·9	E	22	30·315	30·285	30·227	30·205	48·7	35·4	WNW
23	30·258	30·246	30·187	30·220	54·3	40·0	ENE	23	30·159	30·136	30·050	30·028	53·8	47·9	WSW
24	30·244	30·320	30·306	30·357	58·6	45·4	W	24	30·134	30·248	30·272	30·293	53·1	41·3	WNW
25	30·346	30 330	30·211	30·139	61·2	46·7	S	25	30·219	30·145	29·948	29·754	52·3	41·0	S
26	30·021	29·953	29·852	29·815	57·0	47·7	S	26	29·623	29·637	29·611	29·618	45·8	48·1	WSW
27	29·785	29·772	29·730	29·738	59·9	55·1	S	27	29·633	29·676	29·629	29·650	50·1	40·0	NNE
28	29·739	29·796	29·840	29·852	62·0	51·0	SW	28	29·603	29·479	29·508	29·609	54·1	41·2	SW
29	29·976	29·965	29·838	29·695	61·0	52·7	SSW	29	29·625	29·437	29·134	29·389	56·3	46·4	SSW
30	29·559	29·697	29·821	29·916	58·7	43·7	NW	30	29·495	29·550	29·512	29·538	49·2	38·4	W
31	29·955	30·049	30·101	30·151	55·0	40·3	W	31	29·550	29·737	29·814	29·732	49·7	38·9	W

NOVEMBER, 1899.

Date.	KEW. Barometer. 4 A.M.	10 A.M.	4 P.M.	10 P.M.	Temperature. Max	Min.	Direction of wind at noon.	Date.	GLASGOW. Barometer. 4 A.M.	10 A.M.	4 P.M.	10 P.M.	Temperature. Max	Min.	Direction of wind at noon.
1	30·077	29·996	29·790	29·657	55·1	35·4	S	1	29·656	29·604	29·488	29·336	53·9	49·0	sW
2	29·579	29·575	29·495	29·489	50·6	54·4	S	2	29·168	29·194	29·096	29·065	56·3	47·3	SSW
3	29·550	29·555	29·407	29·512	58·9	49·3	S	3	29·013	28·788	28·725	29·050	52·4	43·1	S
4	29·543	29·609	29·616	29·588	60·8	49·3	SSW	4	29·251	29·322	29·076	28·958	58·7	43·2	SSE
5	29·578	29·735	29·797	29·831	60·1	50·4	S	5	29·130	29·322	29·473	29·550	56·4	45·3	sW
6	29·776	29·838	29·938	30·044	52·9	43·1	NNW	6	29·518	29·512	29·616	29·709	48·6	42·3	SW
7	30·048	30·033	29·906	29·720	54·6	38·9	S	7	29·602	29·465	29·279	29·138	54·3	43·5	SSW
8	29·447	29·412	29·430	29·476	56·0	48·0	SW	8	28·936	28·878	28·809	29·114	52·5	45·1	SW
9	29·664	29·875	29·940	29·874	54·3	46·9	W	9	29·415	29·663	29·734	29·645	46·3	40·3	WNW
10	29·529	29·453	29·562	29·884	58·9	47·3	SW	10	29·337	29·069	29·062	29·336	52·4	39·9	S
11	30·043	30·080	30·032	30·203	56·2	43·3	SW	11	29·439	29·534	29·690	29·849	46·3	38·6	NW
12	30·252	30·315	30·349	30·387	53·0	42·0	W	12	29·958	30·077	30·069	30·146	51·6	40·2	WSW
13	30·363	30·389	30·321	30·281	53·4	41·9	SW	13	30·028	30·054	30·012	29·934	53·1	50·1	WSW
14	30·206	30·196	30·195	30·307	53·1	35·2	S	14	29·862	29·884	30·073	30·351	53·0	43·9	SW
15	30·414	30·547	30·561	30·602	50·6	35·7	S	15	30·504	30·607	30·607	30·610	45·1	38·4	E
16	30·616	30·640	30·609	30·633	49·4	40·8	E	16	30·594	30·603	30·593	30·613	46·1	38·3	S
17	30·647	30·690	30·665	30·673	47·1	39·0	ESE	17	30·639	30·660	30·660	30·653	48·3	40·9	W
18	30·655	30·638	30·571	30·540	46·4	31·2	NE	18	30·595	30·581	30·468	30·415	43·1	32·2	E
19	30·473	30·454	30·362	30·322	46·0	34·7	N	19	30·346	30·287	30·175	30·124	50·5	42·2	WSW
20	30·249	30·245	30·267	30·379	48·9	34·2	W	20	30·169	30·260	30·309	30·321	50·5	41·2	E
21	30·410	30·436	30·384	30·395	45·1	34·9	NE	21	30·271	30·241	30·204	30·231	50·1	40·4	WSW
22	30·364	30·425	30·428	30·440	49·1	43·8	W	22	30·155	30·306	30·290	30·249	50·1	44·9	WNW
23	30·406	30·401	30·338	30·334	50·0	44·2	W	23	30·131	30·054	30·026	30·014	52·1	45·9	W
24	30·284	30·278	30·221	30·247	50·2	44·8	WSW	24	29·905	29·852	29·876	29·983	52·8	48·8	W
25	30·277	30·350	30·373	30·423	51·9	46·1	SW	25	30·050	30·136	30·169	30·163	52·3	49·6	W
26	30·406	30·427	30·375	30·369	52·2	43·2	SW	26	30·087	29·984	29·912	29·968	53·3	48·8	WSW
27	30·341	30·376	30·372	30·425	54·7	43·9	WSW	27	30·043	30·109	30·147	30·165	52·8	50·2	W
28	30·432	30·481	30·438	30·465	53·2	40·8	W	28	30·124	30·165	30·182	30·238	53·3	50·9	W
29	30·460	30·487	30·445	30·434	49·0	30·3	W	29	30·244	30·276	30·246	30·222	52·2	47·9	W
30	30·391	30·374	30·259	30·208	44·1	27·6	NW	30	30·164	30·075	29·929	29·789	49·9	46·9	SW

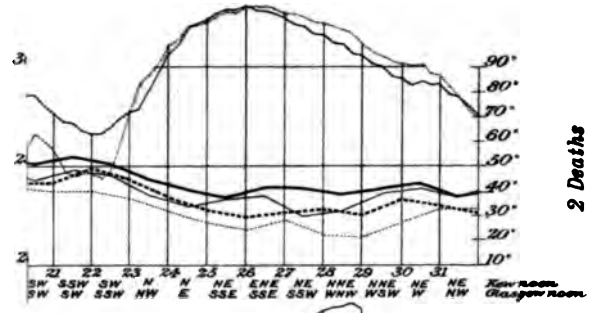
DECEMBER, 1899.

1	30·130	30·108	30·008	30·113	52·9	42·0	SW	1	29·768	29·807	29·883	29·975	50·3	40·9	NW
2	30·205	30·349	30·387	30·451	46·0	34·3	W	2	30·128	30·280	30·365	30·402	44·2	34·3	NW
3	30·471	30·538	30·468	30·433	37·0	26·2	N	3	30·389	30·338	30·196	30·050	48·1	32·3	SE
4	30·318	30·267	30·166	30·148	49·0	36·7	SW	4	29·940	29·926	29·926	30·025	53·3	47·7	W
5	30·127	30·143	30·099	30·058	50·9	46·1	W	5	30·064	30·061	29·981	29·899	51·1	39·3	E
6	29·980	29·904	29·744	29·665	54·0	47·9	SSW	6	29·770	29·689	29·590	29·515	47·4	40·5	E
7	29·616	29·628	29·607	29·706	53·2	41·4	W	7	29·562	29·654	29·708	29·756	47·8	44·1	E
8	29·742	29·845	29·921	30·062	41·5	33·2	E	8	29·752	29·848	29·970	30·062	44·5	33·6	SE
9	30·113	30·219	30·246	30·244	36·2	30·3	E	9	30·155	30·188	30·160	30·163	36·3	31·1	NNE
10	30·178	30·134	30·059	30·083	37·1	30·2	SE	10	30·019	30·031	30·052	30·109	37·4	29·1	ESE
11	30·080	30·105	30·067	29·956	32·5	27·1	N	11	30·114	30·073	29·860	29·647	34·4	27·3	SE
12	29·774	29·791	29·813	29·805	34·2	27·6	SE	12	29·647	29·774	29·862	29·758	33·4	22·5	NE
13	29·695	29·660	29·496	29·482	34·0	25·9	SE	13	29·607	29·451	29·374	29·475	34·7	23·1	E
14	29·494	29·584	29·628	29·732	31·2	21·3	NE	14	29·588	29·645	29·672	29·720	33·9	21·6	W
15	29·792	29·939	29·963	29·978	28·5	23·4	NW	15	29·728	29·756	29·702	29·621	38·1	23·2	WsW
16	29·920	29·903	29·867	29·872	41·3	23·6	SE	16	29·508	29·508	29·553	29·689	43·2	37·4	SSE
17	29·893	29·959	29·958	29·998	36·2	26·0	E	17	29·852	29·980	30·052	30·081	42·1	32·2	E
18	30·015	30·050	30·069	30·102	39·5	35·7	N	18	30·068	30·058	30·035	30·009	40·4	35·2	E
19	30·117	30·159	30·132	30·137	38·7	30·2	E	19	29·978	29·979	29·993	30·062	41·1	34·3	SE
20	30·130	30·146	30·147	30·202	39·6	29·1	E	20	30·085	30·113	30·152	30·218	39·1	34·6	SE
21	30·240	30·301	30·301	30·314	39·0	35·2	NE	21	30·250	30·307	30·314	30·325	39·4	34·8	E
22	30·257	30·214	30·089	30·037	37·2	33·3	E	22	30·252	30·165	30·035	29·984	37·8	33·1	E
23	29·984	30·059	30·075	30·100	37·4	31·6	NNE	23	29·952	29·955	29·852	29·802	38·4	31·2	E
24	29·975	30·013	29·989	29·941	44·2	31·2	SW	24	29·805	29·801	29·723	29·730	43·4	31·3	WSW
25	29·865	29·913	29·883	29·845	41·8	33·7	WNW	25	29·709	29·687	29·622	29·507	39·1	32·6	W
26	29·682	29·563	29·456	29·433	42·0	33·1	SW	26	29·434	29·448	29·419	29·412	34·2	26·0	NE
27	29·414	29·466	29·518	29·596	33·1	26·3	NNE	27	29·412	29·451	29·463	29·529	29·4	22·4	NW
28	29·541	29·463	29·171	28·974	37·2	26·9	E-E	28	29·523	29·498	29·291	29·007	33·9	18·0	E
29	28·796	28·612	28·436	28·562	42·2	45·0	S	29	28·735	28·567	28·430	28·401	39·1	32·9	E
30	28·440	28·687	28·749	29·033	47·1	37·0	SW	30	28·422	28·522	28·618	28·675	41·4	37·8	SSW
31	29·429	29·661	29·751	29·851	45·8	33·6	SW	31	29·924	29·214	29·492	29·627	42·3	34·2	WSW

INIMA TEMPERATURES AND THE DIRECTION
OGETHER WITH THE EXPLOSIONS
'LAND.

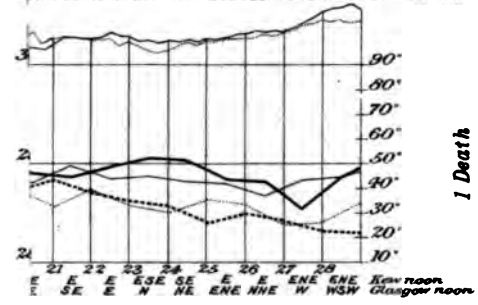
1899.

JANUARY.



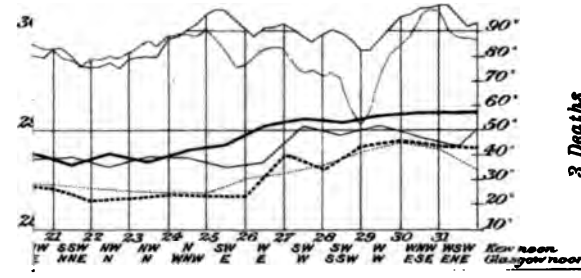
2 Deaths

FEBRUARY.



1 Death

MARCH.



3 Deaths

NOVEMBER. 1899.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.
1	30·077	29·996	29·790	29·657	55·1	35·4	S	1	29·656	29·604	29·488	29·326	53·9	49·0	SW
2	29·579	29·575	29·495	29·489	59·6	54·4	S	2	29·168	29·194	29·096	29·065	56·3	47·3	SSW
3	29·550	29·555	29·407	29·512	58·9	49·3	S	3	29·013	28·788	28·725	29·050	52·4	43·1	S
4	29·543	29·609	29·616	29·588	60·8	49·3	SSW	4	29·251	29·322	29·076	28·958	58·7	43·2	SSE
5	29·578	29·735	29·797	29·831	60·1	50·4	S	5	29·130	29·322	29·473	29·550	56·4	45·3	SW
6	29·776	29·838	29·938	30·044	52·9	43·1	NNW	6	29·518	29·512	29·616	29·709	48·6	42·3	SW
7	30·048	30·033	29·906	29·720	54·6	38·9	S	7	29·662	29·465	29·279	29·138	54·3	43·5	SSW
8	29·447	29·412	29·430	29·476	56·0	48·0	SW	8	28·936	28·878	28·809	29·114	52·5	45·1	SW
9	29·664	29·875	29·940	29·874	54·3	46·9	W	9	29·415	29·663	29·734	29·645	46·3	40·3	WNW
10	29·529	29·453	29·562	29·894	58·9	47·3	SW	10	29·337	29·069	29·082	29·336	52·4	39·9	S
11	30·043	30·060	30·032	30·203	56·2	43·3	SW	11	29·439	29·534	29·690	29·849	46·3	38·6	NW
12	30·252	30·315	30·349	30·387	53·0	42·0	W	12	29·958	30·077	30·069	30·146	51·6	40·2	WSW
13	30·383	30·389	30·321	30·281	53·4	41·9	SW	13	30·028	30·054	30·012	29·934	53·1	50·1	WSW
14	30·208	30·196	30·195	30·307	53·1	35·2	S	14	29·862	29·884	30·073	30·351	53·0	43·9	SW
15	30·414	30·547	30·561	30·602	50·6	35·7	S	15	30·504	30·607	30·607	30·610	45·1	38·4	E
16	30·616	30·640	30·609	30·633	49·4	40·8	E	16	30·594	30·603	30·583	30·613	46·1	38·3	S
17	30·647	30·690	30·665	30·673	47·1	39·0	ESE	17	30·639	30·660	30·660	30·653	48·3	40·9	W
18	30·655	30·638	30·571	30·540	46·4	31·2	NE	18	30·595	30·581	30·466	30·415	43·1	32·2	E
19	30·473	30·454	30·362	30·322	46·0	34·7	N	19	30·346	30·287	30·175	30·124	50·5	42·2	WSW
20	30·249	30·245	30·267	30·379	48·9	34·2	W	20	30·169	30·260	30·309	30·321	50·5	41·2	E
21	30·410	30·436	30·384	30·395	45·1	34·9	NE	21	30·271	30·241	30·204	30·231	50·1	40·4	WSW
22	30·364	30·425	30·428	30·440	49·1	43·8	W	22	30·155	30·306	30·290	30·249	50·1	44·9	WNW
23	30·406	30·401	30·338	30·334	50·0	44·2	W	23	30·131	30·054	30·026	30·014	52·1	45·9	W
24	30·284	30·278	30·221	30·247	50·2	44·8	WSW	24	29·905	29·852	29·876	29·983	52·8	48·8	W
25	30·277	30·350	30·373	30·423	51·9	46·1	SW	25	30·050	30·136	30·169	30·163	52·3	49·6	W
26	30·406	30·427	30·375	30·369	52·2	43·2	SW	26	30·087	29·984	29·912	29·968	53·3	48·8	WSW
27	30·341	30·376	30·372	30·425	54·7	43·9	WSW	27	30·043	30·109	30·147	30·165	52·8	50·2	W
28	30·432	30·481	30·438	30·465	53·2	40·8	W	28	30·124	30·165	30·182	30·238	53·3	50·9	W
29	30·460	30·487	30·445	30·434	49·0	30·3	W	29	30·244	30·276	30·246	30·222	52·2	47·9	W
30	30·391	30·374	30·250	30·208	44·1	27·6	NW	30	30·164	30·075	29·929	29·789	49·9	46·9	SW

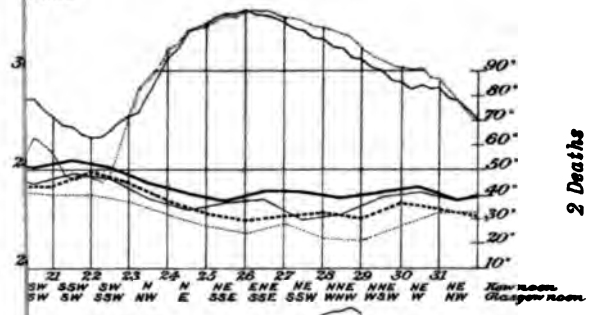
DECEMBER, 1899.

1	30·130	30·108	30·008	30·113	52·9	42·0	SW	1	29·768	29·807	29·863	29·975	50·3	40·9	NW
2	30·205	30·349	30·367	30·451	46·0	34·3	W	2	30·128	30·290	30·365	30·402	44·2	34·3	NW
3	30·471	30·538	30·468	30·433	37·0	26·2	N	3	30·389	30·338	30·186	30·050	48·1	32·3	SE
4	30·318	30·267	30·166	30·148	49·0	36·7	SW	4	29·940	29·926	29·926	30·025	53·3	47·7	W
5	30·127	30·143	30·099	30·058	50·9	46·1	W	5	30·064	30·061	29·981	29·899	51·1	39·3	E
6	29·980	29·904	29·744	29·665	54·0	47·9	SSW	6	29·770	29·699	29·580	29·515	47·4	40·5	E
7	29·616	29·628	29·607	29·706	53·2	41·4	W	7	29·502	29·651	29·708	29·756	47·8	44·1	E
8	29·742	29·845	29·921	30·062	41·5	33·2	E	8	29·752	29·848	29·970	30·092	44·5	33·6	SE
9	30·113	30·219	30·246	30·244	36·2	30·3	E	9	30·155	30·188	30·160	30·103	36·3	31·1	NNE
10	30·178	30·134	30·059	30·083	37·1	30·2	SE	10	30·019	30·031	30·052	30·109	35·4	29·1	ESE
11	30·080	30·105	30·067	29·956	32·5	27·1	N	11	30·114	30·073	29·860	29·657	34·4	27·3	SE
12	29·774	29·791	29·813	29·805	34·2	27·6	SE	12	29·647	29·772	29·852	29·758	33·4	22·5	NE
13	29·695	29·600	29·496	29·482	34·0	25·9	SE	13	29·607	29·451	29·374	29·475	34·7	23·1	E
14	29·494	29·584	29·638	29·732	31·2	21·3	NE	14	29·588	29·645	29·672	29·720	32·9	21·6	W
15	29·792	29·930	29·963	29·978	28·5	23·4	NW	15	29·728	29·756	29·702	29·621	38·1	23·2	WSW
16	29·920	29·903	29·867	29·872	41·3	23·6	SE	16	29·508	29·508	29·553	29·629	43·2	37·4	SSE
17	29·893	29·959	29·958	29·998	36·2	26·0	E	17	29·852	29·989	30·052	30·081	42·1	34·2	E
18	30·015	30·050	30·069	30·102	39·5	35·7	N	18	30·068	30·058	30·035	30·009	40·4	35·2	E
19	30·117	30·159	30·132	30·137	38·7	30·2	E	19	29·978	29·979	29·993	30·062	41·1	38·3	SE
20	30·130	30·146	30·147	30·202	39·6	29·1	E	20	30·085	30·113	30·152	30·218	39·1	34·6	SE
21	30·240	30·301	30·301	30·314	39·0	35·2	NE	21	30·250	30·307	30·314	30·325	39·4	34·6	E
22	30·257	30·214	30·089	30·037	37·2	33·3	E	22	30·252	30·165	30·035	29·984	37·8	33·1	E
23	29·996	30·059	30·085	30·140	37·4	31·6	NNE	23	29·952	29·938	29·852	29·862	39·4	31·2	E
24	29·975	30·013	29·989	29·941	44·2	31·2	SW	24	29·805	29·801	29·723	29·730	45·4	31·3	WSW
25	29·865	29·913	29·883	29·845	41·8	33·7	WNW	25	29·709	29·687	29·622	29·507	38·1	32·6	W
26	29·692	29·563	29·456	29·433	42·0	33·1	SW	26	29·434	29·448	29·419	29·412	34·2	26·0	NE
27	29·414	29·466	29·518	29·596	33·1	26·3	NNE	27	29·412	29·451	29·463	29·529	28·4	22·4	NW
28	29·544	29·493	29·171	28·974	45·2	26·9	ESE	28	29·523	29·498	29·291	29·067	34·9	18·0	E
29	28·796	28·642	28·436	28·569	49·2	45·0	S	29	28·735	28·567	28·430	28·401	39·1	32·9	F
30	28·840	29·081	29·189	29·313	47·1	37·0	SW	30	29·422	29·552	29·618	29·675	41·4	37·8	SSW
31	29·139	29·061	29·751	29·851	45·8	33·6	SW	31	29·924	29·214	29·402	29·627	42·3	38·9	WSW

NIMA TEMPERATURES AND THE DIRECTION
OGETHER WITH THE EXPLOSIONS
LAND.

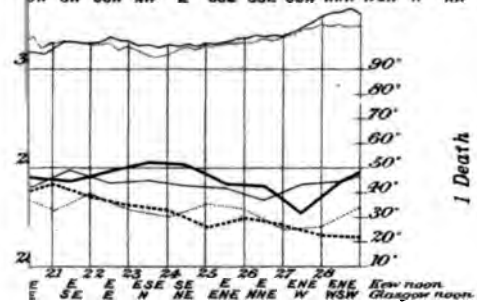
1899.

JANUARY.



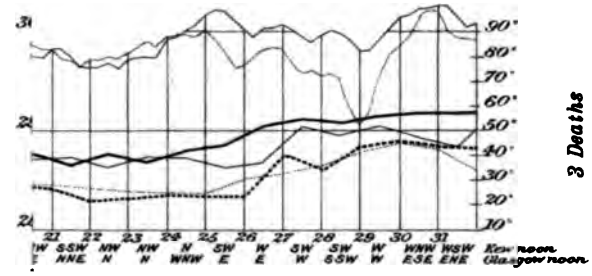
2 Deaths

FEBRUARY.



1 Death

MARCH.



3 Deaths

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EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil and Mechanical Engineers.

S.—Mining Institute of Scotland.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

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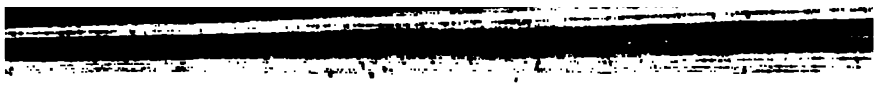
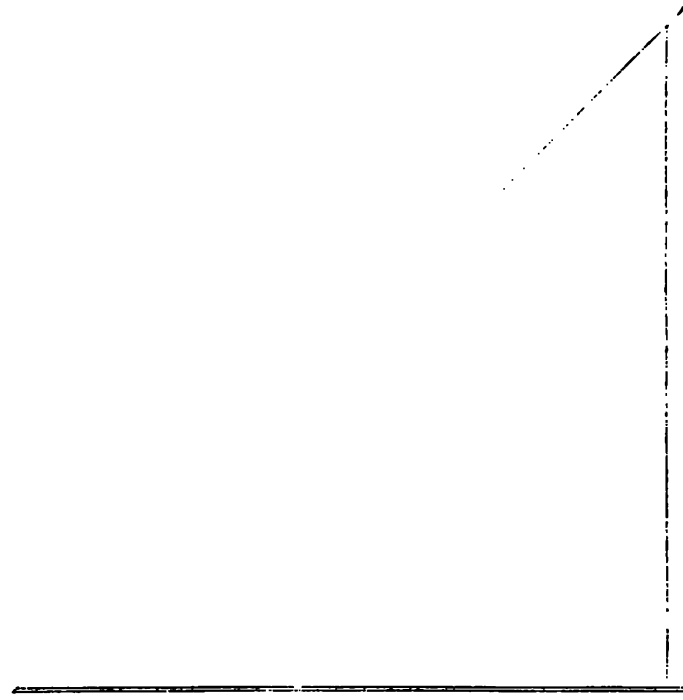
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